ADDRESSES
by
PRESIDENTS
1935-1984

Indian National Science Academy
New Delhi

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1984

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EDITED BY
Archana Sharma, FNA

ASSISTED BY
Asoke Giri and Anusri Banerjee
Centre of Advanced Study, Department of Botany, University of Calcutta
and
Staff
Indian National Science Academy, New Delhi 110 002

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FOREWORD

The Indian National Science Academy, since its inception, has passed through different phases during the growth and development of science and technology in India. The priorities in our national endeavour have been reflected in the expression of thoughts and activities in the forum of the Academy. It has been a most rewarding and valuable experience for me to read the addresses delivered by my predecessors, from time to time, during the tenure of their Presidency. Their ideas and discoveries represent milestones in the progress of science and technology in this subcontinent.

The public in general visualizes a scientist as one living in isolation in his laboratory, engaged in the pursuit of truth. But this vision of private pursuit of science of an individual is rather misleading. Generalization in science is a slow cumulative process and very few scientists and their ideas stand alone in the stream of time. Science in no case is private, but, on the contrary, it is public and a heritage of humanity. Scientific works gradually become discoveries when recognized and accepted by peers in the field and ultimately enter into the fabric of accepted truths. In this process of acceptance and acknowledgement, the role of the Academy is immeasurable. Since its inception the Indian National Science Academy, formerly termed the National Institute of Sciences of India established in 1935, has been continually engaged in promotion of this objective and the role of the successive presidents has been of paramount significance.

Science and technology can impart a lesson which is profound and meaningful and one can no longer question its validity. The successful growth and development of the nation depend to marked degree on the extent to which science and technology are interwoven in the basic issues of national planning. Fortunately in India, utilization of science and technology in programmes of development is enshrined in the constitution. The presidents of this Academy, which is the highest scientific organization of this country and the adhering organization of the International Council of Scientific Union, have, as expected, been deeply involved in the exercise of setting national priorities in planning.

It is in this context that several issues, which are of national importance, have been highlighted by the distinguished presidents from time to time. General topics of common interest, like Science and education, Interface between science and engineering and an Appraisal of the progress of science in India have been discussed with remarkable clarity and deep insight. The projection for our national planning and its stepwise followup have also been mooted under the aegis of this august organization. There has been an introspection from time to time by my predecessors on the role of Academy in relation to the realization of its objective of promoting excellence, projection of Indian Science in International forum, generating a temper of science in this country and lastly safeguarding the interest of scientists of India. A matter of serious consideration at present is its relationship with the government as the highest autonomous scientific organization of this country.

In several areas of science, there have been excellent discourses which served as pace setters for future progress. The ideas in relation to conservation of wild life, so essential for ecological stability, a precise delineation of distribution of animal population in India or of medicinal and economic plants, which in the present decade forms one of the thrust areas of research, were expressed with due emphasis. Very enlightened lectures were delivered on frontiers of medicine, occupational cancer, as well as health and family planning with projection for the future. The achievements of Indian scientists in wheat and roses, symbolizing agriculture and horticulture, have been presented with artistry and accuracy—an essential document for posterity.

It is on the platform of the Academy again that the problem of Indian rivers, including their management, was highlighted leading later towards the basic documents for various river valley projects in the country. The Fellowship was appraised of the possibility of the exploration of upper atmosphere and space and launching of artificial satellites, more than two decades back. The same holds good for the solar control of the atmosphere.

Technical issues, such as the chemistry of the natural products like coumarin and flavonoids or the methodology for the correlation of Archaean rocks, also formed the themes of some of the most illuminating addresses. The emergence of new biology was visualized with the realization of biology coming of age as a conceptual and quantitative science. The Fellowship was also addressed on the fundamentals of the basic philosophy of scientists—the search for truth or the human implication of science.

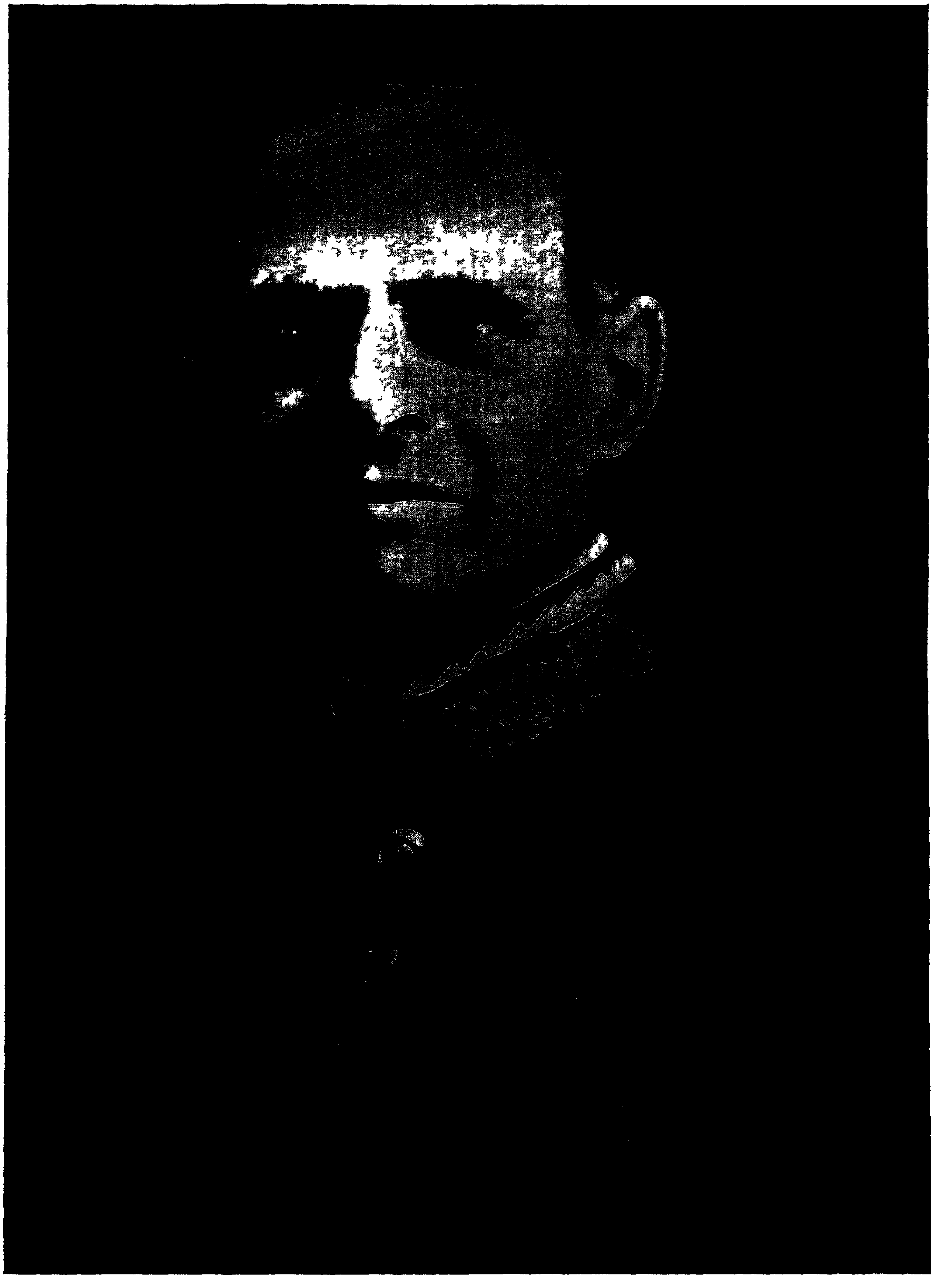
This compilation of addresses is a remarkable mixture of general ideas, technical details, and issues of national relevance—all presented in a fashion that each proclaims the master. It is one of the most prestigious publications commemorating the Golden Jubilee Celebrations of the Academy. The purpose of this endeavour would be fulfilled if the readers have the patience to read, the time to think and analyze the issues, raised at a given period of time by the past presidents of the Academy. It is through such a process, that the beauty and unity of their thoughts are revealed through the apparent diversity of their expressions.

A K Sharma
President
Indian National Science Academy
New Delhi

16.1.1984

Sir Lewis Leigh Fermor, FNA*

(Foundation fellow; President 1935-36)



Sir Lewis L Fermor was born in Peckham near London on September 18, 1880. He was awarded the first class Associateship in Metallurgy from Royal School of Mines in 1901. He joined Geological Survey of India in 1902 and after serving GSI in various capacities, he retired as its Director in 1935 at the age of 55. He was the first President of the National Institute of Sciences (now Indian National Science Academy, 1935-36), the Fellow of the Royal Society of London (1934) ; President, Indian Science Congress (1933), Mining and Geological Institute of India (1922), Asiatic Society of Bengal (1933) and Institute of Mining and Metallurgy, London (1951). He was awarded 'Bigsby Medal' of Geological Society, London (1921), the first 'PN Bose' Medal of the Asiatic Society of Bengal and was made a Knight Bachelor (1935).

His major interest was in Archaean geology and in the different types of igneous and metamorphic rocks occurring in the different regions of India. His principal contribution was to the pre-cambrian rocks of Peninsular India, particularly in Madhya Pradesh and Maharashtra, with their rich mineral wealth.

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*died in 1954.

Inaugural Address to the National Institute of Sciences of India

THE ORGANISATION OF SCIENTIFIC RESEARCH IN INDIA

L L Fermor

(delivered at Calcutta, 1935)

I. Introduction

My first duty, a duty that is also a pleasure, is to thank the Fellows of the National Institute of Sciences of India for the great honour they have done me in electing me their first President. In accepting this office I feel a heavy sense of responsibility; for in the first year of a new organisation many points have to be decided and precedents to be created that must inevitably affect the future procedure and history of the society. But you may be assured that I shall do my best to justify the trust you have placed in me.

Normally the President at the Annual General Meeting will probably think it suitable to deliver an address, of which the major theme will bear upon his own science: probably taking account also of related sciences This, however, is not an Annual General Meeting, but an Inaugural Meeting, at which an address on my own subject, geology, would be unsuitable. Instead it is desirable to clarify our ideas about our National Institute: and this can best be done by sketching briefly the development of scientific research in India so as to show the position of our National Institute of Sciences with reference to other scientific organisations: followed by a discussion upon what our National Institute should do. On attempting to construct a continuous story, I found, however, that it would prove too long for one address; and as I am due to give a Presidential Address to the Asiatic Society of Bengal on February the 4th, and as the Asiatic Society has been the pioneer in scientific research in India, it appeared to me suitable to divide my subject into two sections and to give to the Asiatic Society the portion dealing with the development of science in India up to the end of the 19th century, discussing on the present occasion the developments in the present century leading to the foundation of this National Institute of Sciences of India. Although this course is like putting the cart before the horse it is obviously suitable in view of the dates of founding of the Asiatic Society and the National Institute respectively.

Development of Science in Europe: In the second address I refer to the birth of science during the golden age of Greece in the period 450 to 400 B.C. in Athens, to the period of darkness that descended upon the world after the break up of the Roman Empire, until the Renaissance or rebirth of learning in Europe in the 13th to 16th centuries, leading to the foundation of the Royal Society of London in 1660 and of the *Académie royale des sciences* in France in 1666. I mention particularly that the French Academy of Sciences now forms with four other Academies for other branches of learning what is now called the Institute of France, but which, at an earlier stage of its existence, had a longer title, namely *L 'Institut nationale des sciences et des arts'*, that is to say, 'The National Institute of Sciences and Arts'.

Hindu and Arab contributions: I mention also the part played by the Hindus and the Arabs in their contributions to science during the dark ages in Europe; that Hindu science appears to be partly indigenous and pre-Greek and partly based on Greek influence; and that Arab science was built upon Greek and Hindu science.

The Asiatick Society: I mention also that the introduction of western science and learning into India appears really to date from the arrival in Calcutta of Sir William Jones, a Puisne Judge of the Supreme Court at Fort William in Bengal in 1783, followed by the foundation in 1784 of the Asiatick Society, a society for the study of the antiquities, arts, sciences, and literature of Asia.

The Indian Museum: I allude to the various offshoots from the activities of what is now called the Asiatic Society of Bengal in the foundation of the Royal Asiatic Society of Great Britain and Ireland, with the establishment of branches at Bombay, Madras, Colombo, and Singapore; of the foundation of the Indian Museum based on the collections of the Asiatic Society, and of the establishment of various scientific departments of the Government of India, some of which can be traced directly to the influence of the same Society.

Scientific Services: I mention also that the oldest scientific services in India appears to have been Trigonometrical Survey of the Peninsula in 1800, changed to the Great Trigonometrical Survey in 1818—now the Geodetic Branch of the Survey of India—, and the Geological Survey of India, founded in 1851. These two Departments, with the Medical Services, appear to have been the pre-mutiny, i.e. pre-Crown, scientific services of India. There were also Assay Masters at His Majesty's Mint, Calcutta, at least as early as 1792. I also mention that the oldest universities are those of Bombay, Calcutta, and Madras, all founded in 1857.

Societies: Although by the end of the 19th century several scientific services had been formed in India and had established their own journals, memoirs, and records, yet their officers still contributed freely to the publications of the Asiatic Society of Bengal, which continued to be a great depository of the results of research in all branches of science and letters. In fact, until the end of the 19th century there were hardly any other scientific societies, not to mention scientific societies of note; but amongst them the Bombay Natural History Society, founded in 1883, held and still holds a notable place. Mention should also be made of the Indian Association for the Cultivation of Science established in Calcutta in 1876 and formerly engaged mainly in teaching, but now a research association.

II. The Development of Scientific Research in India in the Twentieth Century

A. Specialist Organisations

Specialist Societies: In the present century we have entered on a new stage in the development of scientific research in India, a period characterised by the formation of numerous specialist scientific societies and numerous Government research institutes. In the matter of specialist scientific societies the geologists gave an early lead with the foundation of the Mining and Geological Institute of India in 1906. The Indian Mathematical Society was started in 1907 in Poona as the Indian Mathematical Club; at present the office thereof is in Nagpur, whilst the Society's Journal is published in Madras. This was followed by the Institution of Engineers (India), founded in 1921, with its head quarters in Calcutta, but with branches at several other important towns; the Indian Botanical Society, with a peripatetic headquarters, but with a journal published in Lucknow, was also founded in 1921; the Indian Chemical Society, with its headquarters in Calcutta, was founded in 1924, as also the Geological, Mining, and Metallurgical Society of India; whilst in the past year, three all-India societies have been founded in Calcutta, namely the Indian Physical Society, the Indian Society of Soil Science, and the Indian Physiological Society. There is also the Society of Biological Chemists founded at Bangalore and the Institution of Chemists (India) founded in Calcutta in 1927; and of societies of more restricted geographical scope, one may mention the Calcutta Mathematical Society founded in 1908.

Research Institutes: In addition to the Government scientific services supported by funds from Central Revenues, there are also in India several research institutions similarly supported. Of these we may enumerate in chronological order of foundation the Imperial Institute of Veterinary Research at Muktesar, which commenced life as the Imperial Bacteriological Laboratory at Poona in 1890, moved to Muktesar in 1893, and assumed its present title in 1925: the Imperial Agricultural Research Institute at Pusa (1903): the Central Research Institute at Kasauli (1906)· the Imperial Forest Research Institute at Dehra Dun (1906): and the All-India Institute of Public Health and Hygiene in Calcutta (1934). There are also several other well-known research institutions principally medical, provincially administered, at which high-class research work is in progress, e.g. the School of Tropical Medicine, Calcutta, and the Haffkine Institute, Bombay.

Further, there is the Indian Institute of Science at Bangalore founded in 1911 and supported mainly by private bequests supplemented by Government grants and directed to research and advanced scientific education.

The Universities: Finally, we must mention the Universities, which, as their title indicate, may be concerned with all branches of knowledge. The oldest universities in India are those of Bombay, Calcutta, and Madras, all of which were founded in 1857, followed by the University of the Punjab in 1882 and University of Allahabad in 1887. In addition, during the present century a considerable number of additional universities have been founded. In these universities chairs of Mathematics, Chemistry, and Physics are almost universal and, in addition, most universities have chairs of Botany and Zoology, but only a small proportion of them have chairs of Geology. During the past decade much work of high quality has come from the universities, but happily the tendency is for our university friends to offer the results of their researches for publication by one of the existing scientific societies rather than for the universities to start their own journals.

B. CO-ORDINATING ORGANISATIONS

With this multitude of new bodies—services, societies, universities, research institutes—coming continuously into being, with a resultant tendency towards greater and greater specialisation and consequent isolation of workers, there is an increasing need for organisations directed to counteracting fissiparous tendencies so as again to bring men of science and other branches of learning back to a common fold providing for a free exchange of views: a result that can be secured either on a comprehensive basis enabling the co-operation of all branches of learning, or at least of all branches of science, or upon a compartmental plan in which allied groups of sciences are brought together.

At the beginning of this century the only organisation directed to this end in a really comprehensive manner was the Asiatic Society of Bengal, to which abundant reference has already been made.

The Board of Scientific Advice: In 1902, however, the Government of India made provision for the co-ordination of official scientific enquiry in a Board of Scientific Advice. This Board was formed in accorance with a Government of India Resolution dated 28th August, 1902, the Board consisting originally of the following officers:

The Surveyor-General of India.
The Meteorological Reporter to the Government of India and Director General of Observatories.
The Director, Geological Survey of India.
The Director, Botanical Survey of India.
The Superintendent, Natural Historical Section, Indian Museum (now the Director, Zoological Survey of India).
The Inspector-General of Forests.
The Inspector-General of Agriculture,

The Inspector-General, Civil Veterinary Department.
The Reporter on Economic Products to the Government of India.

In addition, the Secretary to the Government of India in the Department of Revenue and Agriculture was *ex-officio* President, whilst the Director, Botanical Survey of India, was Secretary.

This Board met periodically, discussed problems of common interest, and published an Annual Report in which the progress of research in India by Government institutions during the year was summarised subject by subject. These Annual Reports though departmental and confined, as was natural, almost entirely to work done under official auspices, were of considerable value; but the activities of the Board were suspended in 1924, and have not since been resuscitated. The reports of the Board were communicated through the Secretary of State for India to the Royal Society, who appointed an Advisory Committee to consider them, and who from time to time furnished the Board and the Government of India with valuable suggestions and advice.

There is now no official Council of Scientific Research in India dealing with science as a whole, although there are two official councils dealing with important sections of scientific research. One is the Indian Research Fund Association and the other the Imperial Council of Agricultural Research.

Indian Research Fund Association: The Indian Research Fund Association was founded in 1911, is located in Delhi and Simla, and is in receipt of funds from the Central Government now enormously reduced as a measure of retrenchment. It is entrusted with the duty of organising medical research at several research institutes throughout India and of deciding the allocation of available funds. In this the Association takes the advice of an 'Annual Research Workers' Conference, held in Calcutta.

Imperial Council of Agricultural Research: The Imperial Council of Agricultural Research was formed in 1929 as a result of the Report of the Royal Commission on Agriculture, and is in receipt of a substantial annual Government grant for purposes of research in agriculture including veterinary research. The funds are allocated to agricultural and veterinary research organisations throughout India, the Council holding periodic meetings in Delhi and Simla for the purpose of determining this allocation.

The Indian Science Congress Association: The isolation of certain scientific workers, to which I have already alluded, is partly the *geographical isolation* of those who live in places where there are but few scientists, and partly the *specialist isolation* of large numbers of scientists one from another due to their specialisation. In order to counteract to some extent both forms of isolation Prof J L Simonsen of Madras and Prof P S MacMahon of Lucknow, both Professors of Chemistry, proposed in 1911 the formation of an Indian Association for the Advancement of Science, analogous to the British Association. As a result, the Indian Science Congress was born, the inaugural meeting being held in 1914 in the rooms of the Asiatic Society of Bengal under the patronage of Lord Carmichael and the Presidentship of Sir Ashutosh Mookerjee. This Congress, which has since become an Association, meets annually, moving from one important city to another on a plan analogous to that adopted by the British Association, so that during 22 years, 10 different centres of research have been visited. The great success of this organisation is shown by the large numbers of scientists from all parts of India who now attend the annual sessions and the corresponding magnitude of the annual volume of published *Proceedings*. Although in its annual activities the Association is peripatetic, yet it requires a permanent office, and this, in fact, is provided in Calcutta by the Asiatic Society of Bengal, which acts as the managing body of the Congress. There can be little doubt that the Indian Science Congress has proved of very great benefit in promoting intercourse between the scientists of all parts of India and all sciences, thereby mitigating both forms of isolation. But this Association meets only once a year, and it is for one week only during 52 that scientists are afforded the opportunity for this fruitful intercourse. During the rest of the year, the centres of research tend to remain in geographical isolation one from another, and at those centres, particularly at the larger ones, the scientists return from the Congress to their specialist isolation, making use as far as possible of specialist societies.

The Academies: There is no doubt that there is a great need for the existence, at the important centres of scientific research, of bodies in which workers in various branches gather not for the reading of specialised papers dealing with minor details and specialist problems, but for the reading and discussion of papers with broader outlines and for the interchange of views. This brings us to the Academy.

During the past year the word *Academy* has been much before us, and to many this term has appeared as a desirable fruit, so that some of the Foundation Fellows of our National Institute, and also some of those who have not yet become Fellows, have expressed their disappointment that we have selected the term *Institute* rather than the term Academy.

Meaning of the term Academy: It seems desirable, therefore, that we should first enquire what the word Academy means. It will surprise most of you to learn that the first Academy was a pleasure garden in Athens which is supposed to have belonged to an ancient Attic hero named Academus. The garden was walled in by Hipparchus, and eventually bequeathed as a public pleasure ground by Cimon to his fellow-citizens of Athens. In this garden the Greek philosopher Plato taught for nearly 50 years; and the Academy thus started lasted from the days of Plato to those of Cicero, that is, for over 300 years.

A philosopher's garden: We see thus that the original Academy dated from about 400 B.C. and was a garden utilised for philosophic teachings and discussions. It was essentially a place where any branch of knowledge could be discussed, and was completely different from our specialised societies of to-day. In this original Academy the old philosophers must have discussed arts and letters, mathematics, and science, as well as philosophy strictly so called; so that a true Academy, without qualification, should be on as broad a basis. The Asiatick Society, now the Asiatic Society of Bengal, is one of the few institutions that complies with such a definition, and it is essentially an Academy of arts, letters, philosophy, and sciences. Another point is that an Academy was essentially a place where philosophers could meet and discuss problems, being essentially suited for personal and local utilisation. From this aspect, therefore, an attempt to found an Academy to serve so large an area as the whole of India is probably misdirected effort, until rapid means of transport become very much cheaper than they are at present. From this consideration it seems also to follow that the promotion of the regular intercourse of the men of letters and science throughout India is only feasible in the first instance on a regional basis, so that each important region, in which there is any volume of research, should have its own Academy, preferably of both science and letters jointly, but otherwise Academies of science and letters separately. It is impossible to foresee at present what number of Academies of Science so large a country as India really needs. It will be for the scientists in different parts of India to settle this by deciding whether they prefer to walk and talk in their own gardens of philosophy, or to make use of distant gardens by means of the letter-box and the printed page.

While Academies, if we go to the original meaning, must, therefore, function locally or regionally in the most important portion of their activities, they can also legitimately make a wider appeal; for now-a-days Academies also undertake the publication for general information of the results of original researches carried out by their members, and for this reason Academies may legitimately expect to secure a wider membership than only local utility would encourage. The Asiatic Society of Bengal, originally founded as the *Asiatick Society*, with the intention of investigating within the geographical limits of Asia 'whatever is performed by man, or produced by nature', has as the result of its researches secured a membership that is not only all-India but international. Nevertheless the major benefits of its activities accrue to those who are within easy reach of its headquarters, and eventually the Society has had added to its name for purposes of identification a territorial or local designation, so that it is now called the Asiatic Society of Bengal, in the same way as *the* Royal Society is the Royal Society of London as distinct from the Royal Society of Edinburgh. In practice, however, the Asiatic Society cannot hope to cater for the frequently recurring (say monthly) needs of the whole of India and, therefore, can have no feeling of jealousy towards other bodies of Academy rank founded in other parts of India.

The United Provinces Academy of Sciences, founded at Allahabad in 1930, was, therefore, on this argument, a desirable creation to provide for the meeting of students of all branches of science in Northern India. This Academy has already secured numerous members outside the geographical limits of the United Provinces, so that its activities, like those of the Asiatic Society of Bengal, are partly local or regional and partly all-India.

When in 1933, the proposal was mooted to found an Indian Academy of Sciences, some of us overlooked the fact that there were already two such Academies in existence,—one called the Asiatic Society of Bengal and the other the United Provinces Academy of Sciences. The proposal, therefore, to found a third Indian Academy, which was entrusted to a Committee appointed by the Indian Science Congress, logically meant either the creation of a fresh garden in another part of India, or of a body to co-ordinate the already existing gardens. Our friends in Bangalore knew all the time that they needed a Society of Academy status with its headquarters in Bangalore. Had they boldly said so at the beginning, the confusion that has arisen in scientific circles during the past year would have been avoided, because it is obviously correct that Southern India should have its own philosopher's garden. However, Bangalore did not do this, so that the general problem was entrusted to the Academy Committee appointed *ad hoc* by the Indian Science Congress. When this took place logic necessitated, though the position had then been analysed by no one, the formation of an Academy of Sciences in Southern India, and possibly of others in Western India, and the Punjab, and then the formation of a co-ordinating body for all the Academies, three, four or five in number.

Object as we may to the manner in which our Bangalore friends cut adrift and abruptly started a new Academy, their action has at least had the merit of revealing the logic of the situation, so that we can appropriately end by welcoming the Indian Academy of Sciences founded at Bangalore, and also agree that this Academy whilst providing a philosopher's garden for Southern India can legitimately have all-India aspirations and activities parallel to those already possessed by the Asiatic Society of Bengal and the United Provinces Academy of Sciences.

III. The Formation of the National Institute of Sciences of India

The National Institute of Sciences - a co-ordinating body: But we still need a co-ordinating body; and that is why it is necessary to found the National Institute. Obviously this co-ordinating body should not compete with the Academies in such a way as to harm them. The prime function of the

Academies is to arrange for regular meetings for philosophic discussions on a suitable periodic basis, say monthly, and for the regular periodic publication of the results of these meetings and discussions, in so far as they are worthy of publication to the world at large. With these activities of the Academies our National Institute should not seriously compete. Instead, our National Institute should have as one of its major activities the co-ordination of the labours of the various Academies. This may prove to be a task of some importance and magnitude, for since India is as large as Europe without Russia, so eventually, as the progress of science so justifies, it may prove desirable to found Academies of Sciences for several of the larger units of territory in India. In France, which is equivalent in size only to one province of India, there are five Academies with a headquarters in Paris.[1] These five Academies are co-ordinated in the Institute of France which, as I have already mentioned, was, in a former stage of existence, called the National Institute of Sciences and Arts. On an analogous basis one of the prime duties of our National Institute should be to co-ordinate the activities of the various Academies of Sciences in India.

We can picture that one day there may be also a *National Institute of Letters*, the purpose of which would be to co-ordinate the activities of Academies of Letters in India, in the formation of which the Asiatic Society of Bengal might appropriately take the lead We can also picture the eventual formation of a *National Institute of Arts* co-ordinating similarly the activities of Academies of Arts in India. Once this has happened, there will be a need for co-ordinating the three National Institutes into a National Institute of Arts, Letters, and Sciences of India, which would be *the Institute of India* equivalent to the Institute of France in its comprehensive scope. For the present it is sufficient for us to found a National Institute of Sciences.

Liaison of National Institute with the Academies: Because of the historical fact that in India our Academies have been formed before our National Institute, it follows that there is at present no organic relationship between the co-ordinating Institute and the co-operating Academies. Each of the Academies is a completely independent body and the extent to which co-ordination of the labours can be effected through the National Institute depends upon the measure of concord that is established. We have arranged, however, for an effective liaison with the three existing Academies by providing on the Council of the National Institute for an additional Vice-President and an additional Member of Council for each of the co-operating Academies to be nominated by the respective Academies. In addition also, partly because common sense requires it, and partly in acknowledgment of our debt of parentage, we are providing for an additional Vice-President and an additional Member of Council to be filled from the Executive Committee of the Indian Science Congress.

Fellowship of the National Institute: We may now, for the benefit of those who have not followed the course of the labours of the Academy, refer to the membership of our National Institute. After full discussion the Academy Committee decided that our new body should have a membership sufficiently restricted to make it a distinction to belong thereto, but at the same time not so limited as to prevent us having at our disposal a useful volume of scientific experience and ability. We decided that it would be suitable to start with 125 Foundation Fellows and to elect 10 new Fellows annually thereafter. In selecting the Foundation Fellows the Academy Committee first assigned quotas on a percentage basis to the various sciences and then appointed small sub-committees to make nominations up to the quotas for the first 100. In order to provide for rectification of inequalities and omissions, should such have occurred, the Academy Committee placed the remaining 25 names for election before those of the first 100 who had accepted Foundation Fellowship. That our methods have met with approval is shown by the fact that out of the 125 scientists invited, 113 have already accepted Foundation Fellowship, 6 only have declined, whilst three unfortunately have died, namely Prof P Sampat Iyengar, late Director of the Mysore Geological Department, Prof S R Kashyap of Lahore, who had been nominated to be one of the Vice-Presidents of the first Council, and Professor V Krishnamurti of Madras.

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[1] Besides Academies at smaller towns such as Montpellier and Toulouse.

Steps have been taken to fill the definite vacancies amongst the Foundation Fellows. Such vacancies as still exist it is proposed to fill during the first year in addition to the annual allotment of ten.

Our Foundation Fellows are distributed throughout the length and breadth of India and include representatives of every branch of science. They include all the Fellows of the Royal Society resident in India, all the past-Presidents of the Indian Science Congress resident in India but one, almost all the heads of the Government of India scientific departments and research institutes, and many distinguished occupants of University professorial chairs throughout India. Although a large proportion of our Fellows are engaged either in teaching or in the pursuit of pure science, yet we have the requisite number of practical men, men whose interests lie in applied science, engineering, and industrial research. The majority of our Fellows belong in addition to one or more of the co-operating Academies, and it may be hoped that as many as possible of our Fellows will think it desirable to belong to the Academy that they can most conveniently treat as their own philosopher's garden.

The Council of the National Institute: In framing our Council we found necessary the large number of 25 in order that after allotting to the headquarters station sufficient members to ensure the possibility of always being able to secure a quorum, we should also be able to have Members of Council in as many of the important centres of scientific research in India as possible. We hope in this way that our Fellows in all parts of India will be kept in touch with the doings of our Council, because it is our intention that the minutes of the Council Meetings shall be sent by post to all Members of Council wherever they are. In addition to these 25 Members of Council representing the National Institute, we have, as already mentioned, made provision for each of the three co-operating Academies, as well as the Indian Science Congress Association, to be represented by an additional Vice-President and an additional Member of Council, selected by the Academy from amongst our Fellows who are members of the respective organisations. Should any other Academies of requisite status be formed, we shall be prepared to allocate the same representation of an additional Vice-President and an additional Member of Council, provided, of course, that such Academies contain the requisite minimum number of our Fellows amongst their membership. In all cases the representatives appointed by co-operating bodies must be Fellows of our National Institute.

IV. The Functions of the National Institute of Sciences

You will now ask what the National Institute proposes to do. Before answering this question I wish to retrace my steps a little. I have mentioned that in Europe each important country has its own Academy of Sciences. These countries being, however, independent countries have no body that can be regarded as the equivalent to our National Institute directed towards co-ordinating the efforts of the Academies of different countries. This want has been long felt in Europe and eventually led to the formation in 1918-19 of the body called the International Research Council, which is a Council for Science not only in Europe, but throughout the world, with its headquarters in

Brussels. This International Research Council operates through National Research Councils, and every important country in Europe as well as in America has its National Research Council; and it is through the National Research Councils of Europe, co-operating with the International Research Council, that the efforts of scientists in different countries are co-ordinated. It is obvious from these remarks that one of the functions of our National Institute should be to act as the organising body of a *National Research Council* in India.

In 1926, the Surveyor-General made a proposal to the Government of India that India should join the International Research Council and certain International Unions formed under the auspices of the Council. This led to a request from Government for further information on the proposal, and eventually in 1930 the Government of India announced that it had been decided that India should join the International Research Council and its Unions of (1) Geodesy and Geophysics, (2) Geography, (3) Astronomy, (4) Biological Sciences, and (5) Radio-Telegraphy. At the time, in the absence of any representative scientific organisation in India that could itself join the Council and arrange for collaboration with the five Unions mentioned, the Government of India were compelled themselves to join this Council, but they were informed that if possible adherence to the Council and Unions should be entrusted to a national scientific organisation, and that other countries had joined through existing scientific academies and institutions, or had set up special scientific bodies for that purpose. The general feeling of the Members of the International Research Council was that the Government of India should not be a member longer than was necessary, lest a political element might be introduced. The Government of India did not consider that any such result need be apprehended from their membership of these organisations, but they wished to assimilate India's position in relation to these bodies, should this be feasible. Accordingly, the Government of India asked the Surveyor-General for advice on this question and requested that he should submit his views after consulting the heads of other scientific departments. In the end, a Committee consisting of the Surveyor-General and the Directors of the Botanical, Geological, and Zoological Surveys considered the various problems in committee and submitted a joint report to Government. This Committee reported that there was in India no body comparable to the Royal Society of London, suitable to undertake the organisation of such a National Research Council, and that, meanwhile, it was desirable to form a Council under Government ægis, with the expenditure connected therewith to be borne by Government. We made definite proposals for the constitution of the Council and of the National Committees for various subjects. Soon after the submission of our report the financial condition deteriorated and no action has been taken in the direction of forming a National Research Council.[1]

When in 1932 the Editorial Board of *Current Science* attempted to elicit the opinion of scientists in India concerning the desirability of forming an Academy of Sciences, I personally replied to the effect that I did not see the need of a new Society for the purpose of reading papers, but that there was a need for a body of scientists of position to render possible the formation of a National Research Council in India, and for this reason I supported the proposal. We had not then realised the full logic of the proposition. But now, in founding this National Institute of Sciences, we have gone a long way towards making it easy for India to form a National Research Council with National Committees in various sciences co-operating with the International Research Council and the International Research

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[1] I may mention that the Government of India also consulted various non-official scientific bodies on this problem.

Unions; and this we may regard as one of the justifications for the formation of our National Institute.

The co-ordination of labours of men of science: Coming now to the question of the aims and objects of our National Institute, these have already been defined in a note issued with the Academy Committee's report. These, as you know, are substantially the same as the aims and objects that were placed before the Academy Committee as a result of the series of resolutions passed by the General Committee of the Indian Science Congress in Bombay in 1934. In my opinion the most important of our objects are to be prepared to co-ordinate the labours of the scientists in India, to effect co-operation between the various bodies of Academy rank, and to render possible the formation of a National Research Council.

Meetings of the National Institute: In my view our Institute does not exist primarily for the purpose of reading papers, so that we shall not need to hold regular monthly meetings. We have suggested that to begin with two general meetings in the year for business purposes will suit our purposes. One of these will be held at the city where the Indian Science Congress meets, so as to render possible the largest attendance of Fellows. The other will be held at the city selected for the business headquarters of the Institute. As due notice will be given of each of these meetings, and as in consequence we shall expect to secure the attendance of a large number of the leading scientists of India, we shall, of course, utilise the opportunity to read and discuss papers of general interest and outstanding merit. We do propose, therefore, on these occasions to give an opportunity to scientists to read papers, and we have, as you know, several papers of high quality offered for reading at the first Ordinary General Meeting of this Institute to be held to-morrow.

An annual review of the progress of science in India: In addition, we propose to resuscitate in a different form the labours of the Board of Scientific Advice by publishing annually a review of the progress of science in India. Our reviews will, however, differ from those published by the Board of Scientific Advice, in that they will take account not only of the labours of scientists employed in Government services, but also of unofficial scientists throughout India.

Consolidated Comptes rendus or Proceedings of Academies: Another matter that is of serious concern to scientists is the increasing number of new scientific journals, so that it is becoming increasingly difficult for any worker in science to keep up with the progress in the branch of science in which he is more particularly interested. From the point of view of a scientist in a particular science, specialist journals are the most convenient, and to this extent those published by bodies of Academy status must be regarded as a source of inconvenience, in that they contain papers on all branches of science that might have been allocated to the respective specialist societies. We all agree, however, that such specialist distribution carried to completion is undesirable, and that in order to facilitate intercourse between men of different sciences, bodies of the Academy type are necessary. It is obvious, therefore, that we require some means by which the productions of all the Academies may be made conveniently accessible to all workers of science in India. For this reason it has been agreed that one of the duties of the National Institute will be to issue a consolidated *Comptes rendus* or *Proceedings* containing summaries of the papers read before all the three co-operating Academies. I can imagine that later it may be asked why we confine our activities to papers read before Academies only, and I can foresee as a development that eventually it may prove desirable to include also summaries of papers published in specialist scientific societies, and in this way to produce a consolidated *Comptes rendus* of all papers read before both Academies and specialist societies in India.

Symposia: Although normally scientific research is severely specialised, so that scientists tend to work in water-tight compartments, yet every science has its borders where it touches one or more other sciences, so that there are fruitful fields or, shall we say, gardens, of possible co-operation along these boundaries. It is, therefore, sometimes suitable and desirable to promote special meetings for the purpose of arranging discussions, by scientists of allied sciences, of problems of joint interest. These discussions are usually known as *symposia* (literally *drinkings together*) and it has been agreed that the arrangement of symposia may be regarded as one of the functions of the National Institute.

A reservoir of scientific knowledge and experience: Another aim of our Institute is to provide a reservoir of knowledge and experience in all branches of science available for application to the study of scientific problems connected with the general welfare of the country. We have not yet worked out our machinery for this; but one possibility is that we may group our Fellows into Committees according to their sciences and that to such Committees the Council will refer special problems for their advice. This means that should Government or any other organisation require advice upon problems of scientific interest, they will be able to rely upon securing the best opinion available in India.

Liaison with Letters: You will remember that in accordance with the resolutions passed in Bombay last January one of our purposes should be 'to promote and maintain a liaison between men of science and men of letters'. The Academy Committee decided during the year that our first task must be to found an organisation devised specifically to suit the needs of scientists and that the question of providing for this liaison with letters must be left for the future. You will, I hope, all agree with me on the great desirability of ultimately effecting such a liaison, which would be brought about ultimately if my vision of National Institutes of Arts and Letters co-operating with our National Institute of Sciences of India should come true. For the present we may consider that the desired liaison has been effected in an indirect way by the fact that one of the Academies co-operating with the National Institute, namely the Asiatic Society, is an Academy both of sciences and of letters.

Management of funds for scientific research: The fifth purpose for which a new organisation was desirable was to 'secure and manage funds and endowments for scientific research'. Upon this point I now wish to speak. Since we have decided upon a limited Fellowship and have also made our subscriptions moderate, it follows that the income derived from Fellows' subscriptions alone will not be sufficient to enable the National Institute to carry out in full the purposes for which it has been founded. We hope, therefore, that the Government of India, and perhaps the provincial Governments, will prove to be in sympathy with the aims and objects of our Institute and that they will realise that this organisation has been founded for the general benefit of science in India, and that, consequently, they will be prepared to contribute towards our financial resources Apart from the funds required for the continuously recurring needs of the National Institute, we shall also be prepared to administer funds presented by men of wealth and position either in aid of the general business of the National Institute, or for the endowment of specific items or branches of research; and the Treasurer will be very glad to receive any donation, however large or however small, either towards the general funds of the Institute, or specifically designated for particular purposes. It is desirable that, as far as possible, contributions should be to the general funds until the finances of the Institute have been placed on a secure footing.

Choice of headquarters of the National Institute: The next point to mention is the choice of the headquarters of our National

Institute. This question has been the cause of much discussion and as long as the position of the new organisation with reference to existing societies was not clearly defined or understood there was bound to be jealousy and anxiety on this point. Past history and present facts point obviously to Calcutta. But had our new society been another Academy in the sense used in this address, I should not have advocated the selection of Calcutta as its headquarters, for there is no room for two Academies of similar aims in one city. Another possibility, and one which was briefly considered, was that of establishing the headquarters of the new body at Delhi, the official capital of India. The total number of scientists resident at Delhi, however, seemed to render this undesirable. The third possibility was an amalgamation with the newly established Academy of Sciences at Bangalore; but this became clearly inadvisable once it was realised that there were already two other Academies of Sciences in India with claims prior to those of the Academy founded at Bangalore. The fourth possibility was for the National Institute to function as a peripatetic body with its headquarters moving every two years according to the change of President. This possibility was considered, but the Academy Committee decided that business requirements and the best interests of the Institute necessitated that the headquarters should be located definitely in one particular centre of research. Our provisional rules do not name any place as the headquarters and there is nothing in them to prevent a change of headquarters at any time should the interests of the National Institute render this desirable. Meanwhile, convenience and common sense appeared to require that we should, to begin with, locate the office of the Institute in Calcutta. Once concord had been established with Bangalore Sir C V Raman himself suggested that this was obviously the logical and correct course to follow. We have accordingly decided to start in Calcutta, but in accordance with the statement made to our Foundation Fellows in our note on the aims and objects of the National Institute, we propose during the first year to take the opinion of our Fellows on this point. If they confirm that the Academy Committee is correct in selecting Calcutta as headquarters they will make a decision in accordance with the course of scientific development in India, recognising that although the Government of India has moved from Calcutta to Delhi, yet it has left behind in Calcutta the headquarters of several of its scientific services, and that on this account, and because of the size of Calcutta with its numerous other scientific institutions, Calcutta is by far the largest centre of scientific research in India. For the present, at least, it appears that it is in the best interest of science that the National Institute should commence work in Calcutta.

As we have decided to make a commencement in Calcutta the Asiatic Society of Bengal has generously offered to provide us with office accommodation; and also to permit us to meet in Council and to hold ordinary meetings of our National Institute as necessary in the rooms of the Asiatic Society of Bengal. In making this offer the Asiatic Society preserves its traditional position as the mother of the development of science in India. We hope also that the Government of India will assume towards our National Institute its traditional position as father by providing suitable funds. For I hope you have realised from my address that the Asiatic Society of Bengal and the Government of India between them are the mother and father of the development of scientific research in India.

V. Conclusion

It is now appropriate that I should, on behalf of the National Institute thank His Excellency Sir John Anderson, the Governor of Bengal, for honouring us with his presence here to-day and for inaugurating our National Institute. It is well known to many of you that Sir John Anderson had a scientific training, and it is clear that had he not devoted his great abilities to administration and had he instead embarked upon the normal career of a worker in science he must have attained to a position of high distinction in the scientific world. It is very appropriate, and we are very fortunate, that our National Institute has been inaugurated by an administrator of scientific training. The date selected for our Inaugural Meeting has proved too late to render possible the presence of members of the Government of India, but I have received personally friendly messages of good wishes for the success of our National Institute from Sir Fazl-i-Husain, Sir Frank Noyce, and Sir James Grigg. I have also received expressions of good will from three of our most senior Fellows, namely Sir J C Bose, Sir P C Ray, and Sir Martin Forster.

In opening this address I expressed my appreciation of the great honour done to me in asking me to be the first President of the National Institute. In this address I have reviewed the development of science in India during the present century starting really with the formation of the Board of Scientific Advice in 1902. As I myself arrived in India in the same year my long service has coincided with the developments discussed in this address. My service is now rapidly approaching its completion, and I take, therefore, this opportunity to say how glad I am to have served in India long enough to take part in the foundation of this National Institute, an organisation that appears to me the logical outcome of the attempts during this century to bring men of all sciences back to a common fold, in counteraction to the fissiparous tendencies caused by the general advancement of science in India, with the resultant formation of so many new bodies—services, societies, universities, and research institutes—devoted to the specialised study of science. Indeed, I hope that in the future, sooner or later, you will succeed in bringing about an effective liaison between science and letters and if, as seems logical, your Fellows decide to confirm Calcutta as the headquarters of our National Institute, and to accept the friendly offer of the Asiatic Society of Bengal, I can picture that one day when National Institutes for Arts and Letters have also been founded, the historic and beautiful building, No. 1, Park Street, which will in any case eventually need rebuilding, will be replaced by a more commodious and comprehensive edifice designed to house not only the Asiatic Society of Bengal, but also the National Institute of Arts, Science, and Letters, with accommodation also for All-India Societies either of Arts, Letters, or Science, the headquarters of which are in Calcutta, and forming thus a magnificent palace of learning in Calcutta equivalent to Burlington House in London. This, I know, is a vision; but because the vision is both logical and possible of fulfilment, it shows that the design of our National Institute of Sciences is on the right lines and that the position allocated to our Institute in the scheme of scientific things in India is the correct one.

unaltered in others, so that rocks which were originally similar have been made to appear dissimilar. To continue our metaphor, not only are many of the pieces of the jig-saw puzzle missing, but the picture of the puzzle has in places been so burnt or scorched as to be almost undecipherable.

Mineral industries of the Archæans : The problem of the reconstitution of this burnt or scorched jig-saw puzzle—a metaphor for which I am indebted to Mr. West—is the problem of the correlation of the ancient schistose rocks and associated crystalline rocks that constitute the Archæan terrane of India. Lest you should think that the problem is of purely academic interest, I would point out that the Archæan rocks of India provide four of India's most important mineral industries—the gold of Kolar in Mysore, the manganese ores of the Central Provinces, Madras, Bombay and other provinces, the iron ores of Singhbhum and Orissa, and the mica of Bihar and Nellore. The Archæan formations also yield the chromite of Mysore and Singhbhum, the copper ore of Singhbhum, the ilmenite, monazite and zircon sands of Travancore, and the rubies, sapphires and spinels of Burma, and many other rocks and minerals of economic importance.

In a memoir, now in the press, entitled 'An Attempt at the Correlation of the Ancient Schistose Formations of Peninsular India',[1] I have, in the introductory section, discussed, at some length, the principles of correlation amongst these old rocks. This renders it unnecessary for me to deal with this subject in as much detail as otherwise might have been suitable, and also makes it possible for me to treat the subject less technically. Geologists who are interested in a more detailed treatment of the subject are referred to the memoir in question. In that memoir, I discuss the use of the term 'Archæan', and restrict it to the ancient crystalline and metamorphosed rocks underlying the Purana formations. These older Archæan rocks are, as a rule, much more highly metamorphosed than the younger Purana formations, as well as being much more highly disturbed, so that the Purana formations rest upon the Archæan rocks with, what geologists term, a great unconformity. In places, however, there is a doubt whether certain highly crystalline formations may not represent younger Purana formations that have been subjected to mountain building operations in the Peninsula, after such operations had ceased elsewhere. Such a possible case is the Delhi system of Rajputana, discussed by Dr Heron in his 'Synopsis of the Pre-Vindhyan Geology of Rajputana', read at our inaugural meeting last year, and published as Vol I, No 2 of the *Transactions of the National Institute of Sciences of India.*

Factors to be considered: As you will judge from the brief account just given of how sedimentary strata are formed, three factors are available in the correlation of unmetamorphosed strata belonging to the fossiliferous section of the geological record:—

(1) Stratigraphical superposition and continuity.
(2) Lithological composition.
(3) Fossil contents.

By the aid of these factors it is usually possible by careful study to place approximately in its correct stratigraphical position any bed in the fossiliferous section of the geological scale and to correlate the detached areas thereof one with another.

When we take up the study of the pre-Cambrian formations, however, the process of correlation proves much more difficult. Even from the younger relatively unmetamorphosed sections of the pre-Cambrian (the Purana) one of the most important criteria—namely recognisable fossil contents—is completely absent in almost all cases. The stratigraphical sequence is still easily determinable, but owing to the long periods of time during which these formations have been subjected to the processes of denudation, often after suffering a moderate degree of folding, strata once continuous have often become dissected into discontinued areas; and if there has been much lateral variation, the break in stratigraphical continuity combined with the absence of fossils may render indecisive all our attempts at correlation, even of comparatively unmetamorphosed strata.[1]

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[1] *Mem. Geol. Surv. Ind.*, LXX.

When we come to the older formations of the pre-Cambrian to which the term Archæan may be applied, not only have we to face the complete absence of fossils, but almost invariably, though not always, the rocks are much more highly folded than with the younger Purana formations. In addition, whilst the Purana formations of the Peninsula are almost invariably free from the effects of batholithic acid igneous intrusion, the older formations are often domed up and intruded by great batholithic granites with associated pegmatites, aplites and quartz veins; and as a result of denudation, combined with the effects of this intrusion, the old formations are frequently found exposed at the surface in detached areas, reducing thereby the possibility of applying the criterion of stratigraphical continuity for purposes of correlation.

Furthermore, this generally greater degree of folding (often intense) with resultant general burial of portions of the strata to zones of high temperature and pressure in the earth's crust, combined with the effects produced by batholithic intrusion, has caused large portions of these older pre-Cambrian formations to suffer a high degree of metamorphism with resultant change of mineral composition. And as the grade of metamorphism attained varies according to the intensity of folding, depth of burial, and amount of intrusion—from that in which an original argillaceous bed has not passed beyond the stage of a shale or slaty shale, to that in which such a rock has been carried to the highest possible grade of metamorphism, e.g. khondalite,—it is evident that in these older rocks we may be deprived for purposes of correlation not only of the criteria of fossil contents and stratigraphical continuity, but even of the criterion of lithological composition that was applicable with the less metamorphosed rocks in cases where particular beds were constant over wide distances without serious lateral variation.

It may be asked what then are the criteria available for use in correlating the ancient schistose formations? The answer is that none are constantly available, but that by taking account of this criterion in one case and that in another, one may expect to succeed in effecting a certain degree of correlation.

The available criteria may be enumerated as follows:

(1) Stratigraphical sequence and continuity.
(2) Structural relationships, e.g. presence of unconformities and relationship to periods of folding.
(3) Relationship to igneous intrusives.
(4) Associated ore-deposits of epigenetic origin.
(5) Lithological composition.
(6) Chemical composition.
(7) Grade of metamorphism.
(8) Uranium-lead ratios and thorium-lead ratios.

I will touch briefly on each of those criteria as illustrated by definite examples derived from the Archæan terrane of Peninsular India.

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[1] As an example we may cite the Raipur limestones of the Chhattisgarh basin. These are now regarded as equivalent to the Panganga limestones of the Godavari valley, and both as equivalent to a stage of the great Cuddapah system of formations of Southern India. The lithologically very similar limestones of the Lower Vindhyans in the Son Valley are regarded as belonging to the lower portion of another, and younger, great system of ancient rocks, the Vindhyans; but it is difficult in the absence of fossils to be certain that the Raipur limestones may not be the link between the Lower Vindhyans and the Upper Cuddapahs, although the general trend of all the evidence is in favour of treating the Lower Vindhyans as distinctly younger than any section of the Cuddapahs.

1. STRATIGRAPHICAL SEQUENCE AND CONTINUITY

Value of detailed mapping: If one tract of old schists be very closely mapped, it may prove possible to establish with some degree of certainty a definite stratigraphical sequence of rocks, which will be of use in attacking the stratigraphy of another not too distant area where similar rocks with about the same grade of metamorphism are found to occur. Thus a very careful survey has been made by me during recent years of a portion of the Sausar *tahsil* in the Chhindwara district, C.P. This work has led to the recognition of a definite sequence of strata now known as the Sausar series.[1] Similar rocks are known to occur as far east as Balaghat, and it may be asserted with confidence that a geologist commencing work in Balaghat would find my Sausar sequence helpful in unravelling the Archæan geology there, and also in assigning to their proper stratigraphical position additional Archæan rock horizons that may have appeared in that neighbourhood. As the two areas, Sausar and Balaghat, are at the two extremities of a tract of country containing various members of the Sausar series, although not always in absolute stratigraphical continuity, this tract of the Central Provinces offers the possibility of the complete unravelling of the Archæan stratigraphy from one end to the other, and the complete correlation throughout that tract of the various horizons of metamorphic rocks.[2]

2. STRUCTURAL RELATIONSHIPS

Conglomerates: I have already mentioned the periodic revolutions that take place in the earth's crust causing sediments deposited at one period to be heaved up and subsequently denuded by the weathering agents, and how in a subsequent period of deposition other beds are laid down upon the upturned edges of the older formation. The break in deposition thus represented is known to the geologists as an *unconformity.* Whereas such unconformities are easy to detect in the younger unmetamorphosed sections of the geologist's stratigraphical column, yet when we come to the ancient Archæan schists, there has been so much folding and metamorphism accompanied by intrusion of igneous rocks that the recognition of stratigraphical unconformities is often difficult. In these unconformities the base of the upper series is frequently represented by a bed of pebbles, the consolidated rock being known as a conglomerate. Unfortunately, in the highly metamorphosed rocks of the Archæans, conglomerates of another type, namely crush-conglomerates, are produced by earth movements from granites, quartzites and other hard and resistant rocks, and the pseudo-pebbles thus formed by crushing are frequently difficult to distinguish from the true pebbles of sedimentary conglomerates. An important task for a field geologist working upon the Archæans is to decide whether the various conglomerates that he meets are true sedimentary conglomerates, indicating possibly the position of an important unconformity, or whether they are only crush-conglomerates indicating, it is true, severe earth movements, but not necessarily a break in the stratigraphical succession.

3. RELATIONSHIP TO IGNEOUS INTRUSIVES

In the Archæan terrane of Peninsular India, there are at least two schistose series separated by an important unconformity. Intrusive into both are batholithic granites, usually gneissic. A batholithic granite is merely a large mass of granite magma derived from below, the base of which has not been seen. It is evident that if we can determine the age of intrusion of these various granite batholiths, we can draw conclusions concerning the ages of the schists into which they are intruded; for obviously the schists cannot be younger than the age of the intrusive granite. Similar use can be made of the basic igneous dykes so common throughout Peninsular India, especially as there are two main series, namely the contemporaneous traps of the Dharwar System, and the Cuddapah lava flows, sills and dykes of later date, the rocks of the former group being distinguished by their almost invariable metamorphism, and those of the latter by their relative freshness due to the comparative freedom of the Peninsula from crustal disturbances since Cuddapah times.

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[1] *Rec. Geol. Surv. Ind.*, LIX, *p.* 78, (1926).

[2] Working in a portion of this belt in the Nagpur district intermediate between Sausar and Balaghat, Messrs. W.D. West and D. S. Bhattacharji have each been able to apply this sequence to their own areas.

4. ASSOCIATED EPIGENETIC ORE-DEPOSITS

Epigenetic ore-deposits are, as the name indicates, deposits of ore of later age than the rocks in which they are enclosed. Such deposits have been formed from materials introduced into the enclosing rocks from elsewhere—usually from gases and solutions derived from intrusive igneous magmas—, and they may, in fact often be regarded as end products of igneous intrusion, for example, of the granites and basic rocks to which reference has been made in the previous section. It seems obvious, therefore, that the presence, in two separated tracts of schistose rocks, of ore-deposits of such closely allied nature that they may, with some confidence, be referred to a similar source, may be utilised as evidence that the schistose rocks of these two tracts are both at least as old as the period of introduction of the ore-deposits in question; and to this extent they may be correlated. As an example, one may cite the gold deposits of Mysore and Singhbhum and the copper deposits of Singhbhum and Sikkim. If reasons can be found for referring the gold deposits of the two tracts named to one period of igneous intrusion, then we can logically deduce that both the Dharwar schists of Mysore and the upper series of of schists of Singhbhum are older than this period of igneous activity. In the same way it may be possible to deduce that the upper series of schists of Singhbhum and the Daling series of Sikkim are both older than the period of intrusion of the igneous rocks to which the introduction of the deposits of copper (and other sulphide) minerals may be ascribed.[1]

5. LITHOLOGICAL COMPOSITION

Metamorphism accentuates small chemical differences: Lithological composition, by which is meant the nature of the rocks composing a given bed, e.g. sandstone, shale or limestone, is only of value as a criterion in correlation in so far as beds continue unchanged over long distances, and have sufficiently distinctive characteristics to permit of their recognition even in disconnected tracts. In the Archæan terranes the various strata have almost always been subjected to some degree of metamorphism, often of great intensity. The effect of metamorphism is to change the lithological aspect of a rock, often so as to render it more distinctive, for metamorphism accentuates the effects of small chemical differences in the original strata. If the grade of metamorphism is approximately the same over a wide area a persistent bed may give rise to a very distinctive type that can be recognised easily whenever it is found. Such a rock may then prove almost as valuable as a zone fossil for purposes of identification. The use of it as a criterion in correlation depends upon the hypothesis that the particular chemical composition of the original unmetamorphosed rock from which it has been derived is not likely to have been repeated exactly. This may seem a bold hypothesis, but there must be cases in which it is applicable: for differences in the composition of unmetamorphosed rocks so small as not to be readily detected without chemical analysis may cause the metamorphosed derivatives to be markedly different.

Metamorphic rocks of uncommon type almost as valuable as zone-fossils: For a metamorphic rock of uncommon type to be repeated exactly requires the combination of two uncommon factors, firstly a sediment of unusual general chemical composition and secondly that out of all of the possible metamorphic variations of this unusual general chemical composition, Nature shall have selected exactly the same variation on each occasion.

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[1] L L Fermor, 'Some Problems of Ore Genesis in the Archaeans of India', *Proc. As. Soc. Beng.*, XV, pp clxxxviii-cxciii, (1919).

The value of the gonditic series as a datum line: As an example we may take the gondite series,[1] which is regarded as a series of metamorphic rocks formed by the metamorphism of manganiferous sediments of varying degrees of purity. Two of the commonest rocks thus produced are gondite (spessartite *plus* quartz) and rhodonite-rock, often with spessartite also. The production of the gonditic rocks requires a moderately high intensity of metamorphism and it seems a fair hypothesis to take all occurrences of gonditic rocks in India as representing a definite stratigraphical horizon, until and unless this is found to lead to results that are repugnant to those otherwise obtained. The type area of the gonditic rocks is the Sausar-Balaghat tract of the Central Provinces. Gonditic rocks have also been found to the west in Narukot State in the Bombay Presidency and in Jhabua State in Central India, and to the east in Gangpur State in Chota Nagpur. In the Central Provinces the gondite series of rocks forms a definite stage (the Mansar stage) in the Sausar series. It appears, therefore, that if the associated schistose rocks of Narukot, Jhabua and Gangpur were carefully mapped, for the purpose of determining the exact position of the gonditic rocks in the schistose sequence in each area, we might have a datum line for correlating the schistose rocks of Narukot, Jhabua and Gangpur with the Sausar series of the Central Provinces. The rocks of Jhabua form part of the great schistose tract of Rajputana and those of Gangpur form part of the great schistose tract of Chota Nagpur and Singhbhum. The gondite horizon may thus eventually enable us to correlate Rajputana, the Central Provinces, and Singhbhum.

6. Chemical Composition

Bulk chemical composition of rock often almost unaltered by metamorphism: The most constant feature of a rock is its chemical composition. It is true that during metamorphic processes substances are in some cases added (e.g. during contact metamorphism) and in other cases removed (e.g. potash from potashfelspar when the latter is converted to sericite; or CO_2 when a siliceous limestone is converted to a calc-silicate rock); but on the whole the bulk composition (except for loss of volatile and liquid constituents) remains constant. So that whilst as a result of metamorphism the physical and mineralogical aspects of a rock may be so profoundly modified that no single original mineral grain or structure persists, yet the bulk chemical composition map remain almost the same. This point is illustrated for example by the complete textural, structural and mineralogical differences between a dolerite and the hornblende-schist derived therefrom: nevertheless the similar chemical composition and, therefore, possible common origin are revealed by bulk analysis.

Consequently when we are comparing tracts characterised by different grades of general metamorphism we may not be able to trace a rock horizon from one tract to another if we take account only of mineralogical composition; but attention to chemical composition may provide the clue.

We may, in fact, make use of chemical composition to recognise the equivalence of rocks now in different metamorphic facies, as examplified, for example, by the possibility that the very highly metamorphosed rocks of the Eastern Ghats are the stratigraphical equivalent of some of the less metamorphosed rocks of Chota Nagpur[1]; or as exemplified by the varying grades of metamorphism of the manganese horizon in the Archæans, characterised by oxidised manganese-ores, where less metamorphosed, and by rocks containing manganiferous silicates (garnets and pyroxenes) where more highly metamorphosed.[2]

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[1] L L Fermor, *Mem. Geol. Surv. Ind.*, XXXVII, pp 206-365, (1909)

[1] *Proc. As. Soc. Beng.*, N.S., XV, p clxxvii, (1919) and *Rec. Geol. Surv. Ind.*, LIII, pp 241-243, (1921)

7. GRADE OF METAMORPHISM

Difference in metamorphic grade not necessarily an index of different age: I have just referred to the fact that variations in the grade of metamorphism, that is to say the intensity of the metamorphic forces applied, may produce mineralogical differences in rocks of the same original mineralogical and chemical composition. The fact that there may be great differences in the intensity with which metamorphic forces are applied even to one continuous tract of rocks is illustrated by both Singhbhum and Rajputana. In Singhbhum to the west of Chaibasa the upper series of the Archæan (the Iron-ore series) is so little metamorphosed that the argillaceous rocks are shales and slaty shales. In Dhalbhum to the east the argillaceous rocks are phyllites and schists. In Rajputana Dr Heron has traced continuously the relatively metamorphosed Delhi rocks of north-eastern Rajputana into the intensely metamorphosed schists of Udaipur 'where the tips of Delhi synclines have reached the zone of flowage'.[3] It is obvious, therefore, that we must not be led by the presence of a great general difference between the grade of metamorphism in two tracts of country into assuming that they are necessarily of different age, the more highly metamorphosed tract being on this view the older. Instead we must be prepared to consider whether the differences may be due, not to difference of age—by which in this case we mean the more prolonged subjection of the more highly metamorphosed tract to metamorphic agencies,—but to the metamorphic forces having been applied with different degrees of intensity to rocks of the same age. If we can effect any chemical correlation between the two tracts, and observe similar general relationships to folding movements and igneous intrusives and to the stratigraphy of the country, we must be prepared for the possibility of general contemporaneity of age, in spite of marked differences in grade of metamorphism. Thus such metamorphically different tracts as Singhbhum, Sausar, and Vizagapatam, may contain rock series of approximately similar age that have been subjected to metamorphic agencies acting with different degrees of intensity, Singhbhum being then the least and Vizagapatam the most highly metamorphosed tract. As the question of grade of metamorphism is of the utmost importance in the consideration of our Indian Archæan schists, it will be appropriate to consider this problem further.

Van Hise's zones of metamorphism: I have referred several times to the metamorphism of the Archæan rocks. The chief metamorphic agents are temperature and pressure, and, as these increase with depth below the surface of the earth, it follows that on the whole the more highly buried a rock is, the more highly does it become metamorphosed and altered. The American geologist, Van Hise, in his famous Treatise on Metamorphism, has divided the known crust of the earth into an upper zone of metamorphism called the *zone of katamorphism*, and a lower zone called the *zone of anamorphism*. The *zone of katamorphism* he defines as the zone in which the alterations of rocks result in the production of simple compounds from more complex ones. This zone, which is, of course, that lying nearer the surface, he subdivides into the belt of weathering, which extends from the surface to the level of ground water, and the belt of cementation, which extends from the ground-water level to the zone of anamorphism. The *zone of anamorphism* is defined by Van Hise as the zone in which the alterations of rocks result in the production of complex compounds from more simple ones. It is, therefore, the lower zone, and it extends from the base of the belt of cementation to as great depths as metamorphic effects extend. Briefly, the zone of katamorphism is that in which compounds are broken *down*, and the zone of anamorphism is that in which they are built *up*.

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[2] *Mem. Geol. Surv. Ind.*, XXXVII, p 312, (1909)
[3] *Rec. Geol. Surv. Ind.*, LX, p 110, (1927)

From the physico-chemical point of view, the distinction between these two zones is of fundamental importance, and these distinctions may be summarised in the following quotation (*l.c.*, p. 186) from Van Hise:

> 'In conclusion of this part of the subject it may be said that in the zone of katamorphism the alterations are mainly controlled by the chemical law that reactions take place with liberation of heat, and this ordinarily results in increase of volume, provided the compounds which form remain as solids. In the zone of anamorphism the reactions are mainly controlled by the physical law that reactions take place with decrease of volume, and this commonly results in chemical reactions with absorption of heat. In the upper zone chemical law is the determinative factor in the reactions; in the lower, physical law. In the upper zone the important chemical reactions are those of oxidation, carbonation (involving desilication), and hydration; in the lower zone the important reactions are those of deoxidation, silication (involving decarbonation), and dehydration. In the upper zone the minerals are few in number, of low specific gravity, and probably of simple molecular structure; in the lower zone the minerals are numerous, of high specific gravity, and probably of complex molecular structure'.

Grubenmann's zones of metamorphism: Grubenmann in his notable work 'Die Kristallinen Schiefer',[1] a work, like Van Hise's 'Treatise', of the first importance to students of metamorphism, recognising this important relationship between the depths to which a rock has been buried and the grade of metamorphism to which it has been raised, has divided metamorphic rocks into three depth zones according to—

1. Temperature.
2. Pressure:
   (*a*) Hydrostatic or uniform pressure.
   (*b*) Stress or directed pressure.
3. Combined effect of temperature and pressure.

In the memoir to which reference has been made, I make use of Grubenmann's nomenclature, but I do not propose to discuss this further here except that it seems suitable to introduce a table adapted from his work summarising the incidence of these factors in the three zones.

The *plus* and *minus* signs in the final column indicate that the predominant chemical interchanges take place according to exothermic and endothermic reactions respectively; by a comparison with the nature of these reactions in Van Hise's zones it will be seen that the change over from the exothermic conditions of Van Hise's upper zone of katamorphism to the endothermic conditions of his lower zone of anamorphism must occur somewhere in Grubenmann's middle zone, the mesozone or zone of meso-metamorphism of the third edition of Die Kristallinen Schiefer.

In the third edition of Die Kristallinen Schiefer by Grubenmann and Niggli (I, pp. 375, 376) the Greek terms epizone, mesozone and katazone are applied to these three depth zones, and the forces of metamorphism characterising them are spoken of as epi-metamorphism, meso-metamorphism and kata-metamorphism. The use of the prefix *kata* in this sense is unfortunate, both because of its previous use by Van Hise (with its implication of *breaking down*, as in the term kataclastic) for his upper zone, and because *kata* is not a prefix of position like *epi* and *meso*. A more suitable prefix is *hypo* and in the table I have substituted 'hypo-zone' for 'katazone' in accordance with my letter to the *Geological Magazine* on this point.[1]

Infra-plutonic zone: Grubenmann's lowest zone passes down into my infra-plutonic zone,[2] but as the eclogites supposed to characterise this zone are nowhere seen at the surface, consideration of this zone does not affect our problem of correlation; although this conception of an eclogitic

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[1] *Geol. Mag.*, LXIV, p 334, (1927).

[2] *Rec Geol. Surv. Ind.*, XLIII, p 43, (1913).

Table

Determining Factors of the Individual Zones				Results	
Zone	Temperature	Hydrostatic pressure	Stress	Predominating form of metamorphism	Thermal effect[2]
Highest Zone (Epizone)	Moderate	Mostly small	Often strong, also lacking	Mechanical and chemical. Formation of principal water-holding silicates	+
Middle Zone (Mesozone)	Higher	Mostly stronger	Often still very strong, also lacking	Chemical (Riecke's principle)	+ (−)
Lowest Zone (Hypozone)	Very high	In many cases very strong	Mostly weak or often quite lacking	Chemical (Slow re-crystallisation, often with retention of form)	−(+)

shell to the earth provides attractive explanations of the manner in which the isostatic balance of mountain and plain is maintained, of the source of deep-seated earthquakes, and of the widespread basaltic lava flows that periodically overwhelm the surface of the earth, as well as of the chondritic meteorites, I must resist the temptation to enlarge upon these matters, especially as I was able to sketch them briefly in an address on 'Earthquakes and Garnets' given to the United Provinces Academy of Sciences last April.

8. Lead-ratios and Helium-ratios

In the previous sections we have been dealing with criteria which are within the legitimate sphere of the geologist who specialises upon the study of the Archæan rocks. It must appear to some of you that in spite of these numerous criteria, since none of them are continuously applicable, and specially because of the confusing effects of variable metamorphism, it must in many cases be difficult or impossible for the geologist to be certain of his results when working amongst these old rocks. This is indeed not infrequently the case. Fortunately, however, the physicists, with the discovery of the fact of the radioactivity of certain elements, and particularly with the discovery that such elements owe their special properties to atomic disintegration, and that from this disintegration a stable element may be produced, have come to the help of the geologist. In this discovery we are witnessing the fashioning of a new weapon for determining the age of minerals and thus the minimum age of the rocks containing them, a weapon that in the absence of fossils is particularly welcome to students of pre-Cambrian geology.[1]

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[1] First Edition, 1904. Second Edition, 1910.
Third Edition, 1924, in collaboration with P. Niggli, under the title'Die Gesteinsmetamorphose'. References, unless otherwise stated, are to the second edition.

[2] For an explanation of the term Warmetönung ('heat-toning') *see* Nernst's 'Theoretical Chemistry', translated by C S Palmer, pp 430, 491, (1895); also Van Hise's 'Treatise of Metamorphism', p 106, (1904).

[1] The contributions of Rontgen, Becquerel, Madame Curie, Rutherford, Soddy, Boltwood and others to the discovery are referred to in Parts III and IV of Volume IV of the 'Physics of the Earth'entitled 'The Age of the Earth', by A. F Kovarik and A Holmes respectively, and entitled respectively 'Calculating the Age of Minerals from Radio-Activity Data and Principles' and 'Radioactivity and Geological Time., See *Bull. National Res. Council of the National Acad. of Sci.*, Washington, DC No. 80, June 1931, pp 73-123 and 124-469.

Lead-ratios: This new weapon is the determination of the ratio in an otherwise fresh mineral (between an ultimate product of disintegration (lead) and the element (uranium or thorium) of whose radioactive disintegration it is the final product. As may well be supposed many experimental difficulties have been encountered in the perfecting of this weapon, and although the accuracy of the method is not complete, yet it has yielded results of a sufficient degree of consistency to show that used with discretion it will ultimately provide a means of correlating the various igneous intrusives of pre-Cambrian age in so far as they yield radioactive minerals.

Prof A Holmes, who has made a special study of the utilisation of these data on radioactivity, has succeeded in drawing up a provisional table (*l.c.*, p. 444) of pre-Cambrian correlation, in which he divides pre-Cambrian times into three sections as follows:[2]

	Lead-ratios
Upper Pre-Cambrian	0.08 to 0·11
Eparaehacan Interval	
Middle Pre-Cambrian .	0·125 to 0 16
Epi-Laurentian Interval	
Lower Pre-Cambrian .	0·185 to 0·2

In this table he shows the pre Cambrian of Fenno-scandia, the Canadian Shield, South and Central Africa, Peninsular India, and Australia. The only minerals from India and Ceylon for which the lead-ratios have been determined are as follows:

Uraninite, Ceylon	0·065
Thorianite, Ceylon .. .	0·08 ca.
Uraninite, Gaya	0·12—0 13 ca.

On these data Holmes places the Ceylon minerals in the Upper Pre-Cambrian, treating the pegmatites from which they were derived as roughly equivalent in age to the Jalor and Siwana granites of Rajputana, which may possibly be of Lower Vindhyan age as stated by Holmes, but are preferably regarded as intermediate in age between the Delhi and Vindhyan systems.[3] The uraninite from Gaya is from pegmatites, that he treats as belonging to younger Archæan granites.

In addition to the uraninite and thorianite mentioned above, India and Ceylon have yielded numerous radioactive minerals, of which monazite, thorite, zircon, and samarskite, may be mentioned as providing scope for much useful work on this problem.

Messrs N A Yajnik and Saral Jang Kohli have investigated the radio-activity of certain Indian minerals, determining the radium contents thereof,[1] but this is useful for our present purpose only in indicating minerals of which the lead-ratios could profitably be determined. The minerals investigated are uranium-ochre and columbite from Gaya, samarskite from Nellore, uraniferous apatite-magnetite-rock from Singhbhum, and cordierite-rock from Travancore. Of these the uranium-ochre from the Gaya district and the samarskite from the Nellore district are by far the most radioactive.

Helium-ratios: Another method that has been investigated is that of helium-ratios, that is of helium to uranium and thorium,[2] dependent on the fact that helium is produced during the disintegration of uranium and thorium. This method has been specially developed by R J Strutt (now Lord Rayleigh). It has not yet proved as reliable as the method of lead-ratios, owing to the facility with which helium, especially if present in quantity, escapes from minerals. The results obtained are thus always minimum values. One of the minerals studied by Strutt is zircon[3] from various localities, which have given helium-ratios on the whole proportional to the geological age. Amongst the specimens investigated are zircons from Ceylon gem gravels, regarded as probably of Upper Pre-Cambrian age by Holmes. Sphenes, phosphatic materials and iron-ores have also been investigated by Strutt for their helium-ratios, and also a number of other minerals from various localities by Strutt and others, including thorianite from Ceylon. A comparison by Holmes of helium-ratios with lead-ratios shows that the age of a mineral calculated from its helium-ratio is rarely over 60 per cent of the true value and is generally less than 40 per cent.

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[2] *See* also A Holmes, 'Radioaktivität und Geologie', *Verh. d. Taturf. Gesellsch. in Basel*, XLI, pp 136-185, (1931); p 157.

[3] A L Coulson, 'The Geology of Sirohi State, Rajputana', *Mem. Surv. Ind.*, LXIII, p. 103, (1933); A M Heron, *Trans. Nat. Inst. Sci. Ind.*, Vol. 1, p 20, (1935)

[1] *Journ. As. Soc. Beng.*, N.S., XX, pp 225-238, (1925)

[2] Holmes, *loc. cit.*, pp 393-426.

According to Holmes,[4] however, the loss of helium from close-grained igneous rocks—especially if they are free from glass—will be a lower order than that characteristic of 'radioactive' minerals.

Dr V S Dubey of Gwalior, partly in collaboration with Dr Günther in Berlin, and partly in collaboration with Holmes, has made a preliminary investigation of these possibilities and has determined the helium-ratios of rhyolites and basalts from Pavagadh Hill in Gujrat and of the Cleveland dyke and Whin Sill in England.

Dr Dubey has also investigated the helium-ratios of the basic rocks of the Morar stage of the Gwalior series, regarded as pre-Cambrian in age and grouped with the Puranas. Three different rocks were analysed with widely divergent results, the age indicated ranging from 203 to 500 million years, the highest result being given by the finest grained rock (a fine-grained basalt flow). Using the latter result only this determination indicates, according to Holmes, a late pre-Cambrian age for the Gwalior basalt. It is evidently considered by Holmes that with these fine-grained rocks of low helium contents there is no substantial leakage of helium to be allowed for.[2]

During his earlier investigations of helium-ratios, Lord Rayleigh (as R J Strutt) found that certain beryls of Palæozoic age from the U.S.A. contained much more helium that could be accounted for by the small traces of radioactive matter of the uranium and thorium series present. Recently Lord Rayleigh has made a special investigation into the helium contents of over 60 specimens of beryl[3]. These, although predominantly of Archæan age, included a considerable number from later geological formations. Taking either the maximum quantities of helium (cubic millimetres per gram of beryl) or the median quantities, it is clear that there is a relationship between helium contents and geological age, showing that the helium has accumulated in beryl during geological time. It is also known that the helium is not derived from uranium or thorium, and the preliminary deduction is that the helium is derived from the atomic disintegration of beryllium[4].

There is a possibility, therefore, that ultimately helium-ratios may provide some guide to the age of beryls and thus of the rocks, usually pegmatites, containing them.

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[3] Holmes, *loc. cit.*, p 402

[4] Holmes, *loc. cit.*, p 411. I do not agree with Dr. Dubey's interpretation of the structure of Pavagadh Hill in accordance with which he regards the acid rock on the summit as a plug, instead of a flow as determined by W T Blanford and myself and recently confirmed by Dr A M Heron [see *Rec Geol Surv Ind*, XXXIV, pp 148-166, (1906), and LXVIII, p 17, (1934)]. According to Holmes the helium-ratios of the rhyolites (felsites of Dubey) are clearly low, so that the rhyolites may be much older than is indicated by Dubey and Holmes.

[1] 'Helium ratios of the basic rocks of the Gwalior series', *Nature*, Vol 126, p 807, (1930)

[2] *Loc. cit*, p 409

[3] 'Beryllium and Helium. I—The Helium contained in Beryls of Varied Geological Age', *Proc Roy Soc* A, CXLII, pp 370-381, (1933)

[4] *Nature*, Vol 131, p 724, (1933)

For the above investigation 17 of the specimens were provided by myself from the collections of the Geological Survey of India[3]. Six out of the first eight specimens arranged in order of helium contents came from India.

Pleochroic haloes: One other method of utilising the radioactive properties of minerals may be mentioned, namely measurement of the rings of pleochroic haloes in biotite and cordierite. Much research on this was done by Joly, but sufficient success in the interpretation of results has not been obtained to render it necessary here to refer further to the problem.[1] Pleochroic haloes have been noticed in various minerals in India, and there is a field for research on this question.

I have dealt with this last criterion of lead-ratios and helium-ratios at some length because it will be of special interest to physicists present; and in order to bring to the notice of our physical and chemical friends, who are equipped with the necessary apparatus and experience to undertake the research, that there is a great field for research on radioactive minerals in India. The Geological Survey of India is in possession of the material, and I do not doubt that my successor as Director—Dr Heron—would be only too glad to help in the provision of material for properly directed investigations. For it must be emphasised that such research will be of no value to the geologist, but will only create confusion, if it is not to the last degree accurate.

III. Conclusion

I hope that this address has not seemed too abstruse to those who are not geologists. In any case, I hope I have succeeded in indicating that we geologists do not practise a science enclosed in a water-tight compartment. We are dependent at every step upon other scientists. Thus we rely upon help from the physicists and chemists in the determination of the physical constants and the chemical composition of minerals and rocks, in the solution of the problems of seismology and geophysics, and in the determinations of the radioactive constants of minerals and rocks; to the botanist and zoologist we look for help in understanding the relationships of the organisms now represented by fossils; we join with the astronomer when we pursue our geology back to the earliest history of our globe and contemplate the relationship of our earth to other stellar bodies.

Although the geologist makes so much use of the researches of other branches of science, he hopes that he provides an adequate *quid pro qoo.* Geology is in a way the science that synthesises all others, as it is the science of the earth upon which we live. The geologist is therefore often able to provide a check to other sciences, and to help with suggestions for research. A classic example of the former is the refusal of geologists to accept the restricted age that physicists and astronomers were formerly prepared to allow to our earth as compared with the requirements of geology to provide for the facts of sedimentation and the evolution of life; the discovery of radioactivity has solved the difference, so that physicists now allow to the geologist the time he wishes. A classic example of the assistance given by geological science to other sciences lies in the fact that the fossils discovered during his stratigraphical researches have provided materials of fundamental importance to the theory of the evolution of life upon the earth.

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[5] They were derived from Mysore, Assam, Nellore and Coimbatore in Madras, Bhandara, Central Provinces, the Bihar mica belt, Ajmer, Kishengarh and Gwalior in Rajputana (possibly all Archaean in age); from Padar in Kashmir (of doubtful age); and from Tavoy in Burma and from Chitral (both probably Mesozoic). One of these specimens, from the Bangalore-Kankanhalli Road, Mysore, contains more than twice as much helium as the beryl of any other locality

[1] Reference may be made to Chapter II of Part IV, by Holmes, pp 159-196, of 'The Age of the Earth', already cited, for a detailed account of the researches into this method.

Both these points have resulted from the researches of the geologist into the stratigraphical succession of the rocks of the earth's crust. It will be seen, therefore, that the general subject of this afternoon's address, the correlation of strata, is one not only of economic interest to the mineral industries and of general interest to the geologist, but is also a subject that has had profoundly important repercussions upon astronomy, physics, zoology and botany. The restricted section of the subject with which I have more particularly dealt takes us back to the primordial days when at one end geology merges with astronomy and at the other end with the appearance of life upon earth.

PROGRESS OF GEODESY IN INDIA

H J Couchman*

(delivered at Hyderabad, 1937)

The study of Geodesy in India has been for many years confined almost entirely to the Survey of India department of the Government of India and as the head of that department, it appears to me to be a suitable subject with which I should deal. I must however explain that I have not personally been connected with this branch of our departmental activities for many years and I can therefore only be the somewhat halting mouthpiece of others.

Geodesy, or earth measurement, is a science with which any survey department is intimately concerned. Without knowledge of the shape, or as it is generally termed the figure, of the earth the mapping of any considerable portion of the earth's surface is impossible, in the sense that the positions of points on that surface cannot be accurately defined by their latitude and longitude, and isolated surveys cannot be connected together.

The making of disconnected maps in India began about the middle of the 18th century but it was not until the end of that century that a start was made to cover India with a network of accurately fixed triangulated points. This network was primarily required for the control of surveys by preventing the accumulation of errors, but it has been used along with triangulated arcs in other parts of the globe to determine the figure of the earth and to this extent its purpose was geodetic.

The year 1802, when Colonel William Lambton measured his first base line near Madras may be taken as the beginning of the study of geodesy in India. This study has continued with little interruption to the present time.

India has been a particularly favourable area for this study. Firstly, with the exception of the United States of America, it is probably the largest developed area under the control of one administration. The difficulties, met with in other continents, in the initiation and co-ordination by different Governments of geodetic work have consequently been absent. Secondly, its shape provides an extremely long stretch of land area on one meridian; from Cape Comorin in a due northerly direction to the foothills of the Himalaya (beyond which accurate geodetic work is hardly practicable) we have some 1,500 miles of country available. The value of this lies in the fact that prior to the electric telegraph the accuracy of astronomical determinations of longitude was in no way comparable to those of latitude. Consequently the earlier attempts to derive the figure of the earth were based on arcs measured along a meridian and have only comparatively recently been extended to arcs along a parallel. Thirdly, in the mountains to the north it possesses the most elevated portion of the earth in close proximity to deep oceans. It has at its very door ample material from which the attraction of local masses can be calculated and analysed, and theories formulated as to the structure of the earth. But it has been fortunate in another way. All these favourable attributes would have been wasted, anyhow for many years, but for the two great pioneers of geodesy in India, Colonel Lambton and Sir George Everest. These two between them controlled the early geodetic work in India for over 40 years and laid down for their successors a lasting framework on which to build.

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*Brigadier Couchman held office of the President against interim vacancy from 1.4.1936 to 31.12.1936.

The earliest years of geodetic study in India were spent in the measurement of base lines and arcs of triangulations and astronomical observations of latitude at selected stations along these arcs. By 1830 sufficient data had been accumulated to enable Sir George Everest to calculate his figure of the earth. The necessity for a recalculation of this figure had been apparent for some years but had obviously to wait until data were deemed to be sufficient. Until then the calculation of latitude and longitude of triangulated points, necessary for the purpose of survey, had to be based on some more or less arbitrary figure and it is known that this arbitrary figure had to be changed several times, as its unsuitability became apparent.

Everest's figure has been used for the computation of the whole of the Indian triangulation and it is therefore of interest to record that it is an oblate spheroid of which the major or equatorial semi-axis is 6377·3 kilometres with an ellipticity* or flattening of $\frac{1}{300{\cdot}8}$. Further investigations have shown that this spheroid is slightly too small, the modern value of the major semi-axis being about 6378·4 kilometres or some 1,200 yards greater, with an ellipticity in the region of 1/295 making the polar semi-axis about half a mile greater than Everest's.

The result of using Everest's spheroid as the reference figure for computing the elements of the Indian triangulation is that India occupies on its maps slightly more than its proper share of the earth's surface. In longitude from Baluchistan to Burma a distance of some 2,500 miles this excess is about 2,500 feet. This excess will cause no embarrassment until our neighbours carry out independent geodetic triangulation and mapping up to our common frontier where each point on the ground will then have two values of latitude and longitude, our own and our neighbours'. Until there is a prospect of this, the immense labour of republishing all Indian maps on a corrected graticule is not worth undertaking. Siam is at present our only neighbour that has carried out accurate triangulation up to the Indian border but as they have so far accepted the Indian values of latitude and longitude for their base station there is no discrepancy in maps.

Deflection of the vertical

The geodetic method of calculating the figure of the earth is to relate the linear distances along a meridian or parallel between fixed points as determined by triangulation with the angular distance as determined by the difference of astronomical latitudes or longitudes. Such a method can only give good results if the instrument to measure the vertical angles necessary for latitude or time is truly horizontal, that is to say tangential to the spheroid of reference which is to be obtained. In the vicinity of large excesses of matter this condition is not obtained, since the mass deflects the vertical. All astronomical measures of latitude or time are therefore in error by the difference between the local vertical or direction of gravity, and the true vertical or normal to the spheroid of reference.

In calculating this spheroid therefore it is clear that stations in the vicinity of very large excesses or deficiencies of matter should be avoided.

With the elements of the spheroid of reference thus obtained the latitudes and longitudes of points fixed by triangulation are calculated and by comparing these values with those obtained astronomically a measure of the angular displacement or deflection of gravity is obtained. It must however be remembered that this measure is not absolute but will vary as the elements of the spheroid, or other figure of reference selected, are changed.

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* If a = major semi-axis (equatorial)
b = minor semi-axis (polar)

than ellipticity $= \frac{a-b}{a}$

When these deflections were obtained at stations near the foot of the Himalaya and it was found, of course, that they were towards the mountains, attempts were made to connect the amount of deflection with the amount of the visible excess of matter. It was soon apparent that such connection presented great difficulties. The calculated effect of the visible excess of matter was in all cases far greater than the observed deflection. At Dehra Dun at the foot of the Himalaya, for example, the calculated deflection was 86 seconds of arc as against an observed value of 37 seconds.

The question was referred about 1853 by Sir Andrew Waugh, the Surveyor-General, to Archdeacon Pratt of Calcutta, a distinguished mathematician, and he propounded his theory of mountain compensation or what is termed isostasy to-day. I return to this theory later; it is sufficient here to remark that the theory did not completely explain the observed deflections.

Other geodetic work

For nearly forty years this aspect of geodesy was not seriously pursued in India no doubt because it was realized that more data was necessary, but in 1901 Sir Sidney Burrard again directed attention to the problem in his famous paper 'On the attraction of the Himalaya mountains upon the Plumb line'. During this interval geodetic work did not cease. India was gradually being covered with a network of primary triangulation, which is even to-day not quite complete, tidal observations were made to determine the mean sea level as a datum for the level net and the first series of pendulum observations to determine the force of gravity were carried out in the late 1860s. The telegraphic connection of India with Europe enabled an accurate calculation of longitude to be made about 1898, incidentally shifting India some 2½ miles west of its previous place on the globe to occupy a position which modern methods and apparatus have shown to be extremely accurate.

Recent progress

The present century has seen a great revival of geodetic study in India. The principal activity has been the accumulation of values of the force of gravity by means of the pendulum and of its direction by astronomical observations already referred to. In 1909 Mr. J. F. Hayford of the United States Coast and Geodetic Survey published his investigations into the theory of isostasy and this was shortly followed in India by preliminary discussions of the correctness of his theory as judged by Indian data.

Hayford's theory stated briefly was that above a certain depth below sea-level the mass in any column of unit area is the same whatever its height, or in other words that mountains and seas are compensated by underlying deficiencies and excesses of density. The theory is practically the same as that of Archdeacon Pratt to which I have referred above but is stated in a more precise way. Hayford's calculations of the depth at which compensation was complete produced the figure of about 70 miles, subsequently reduced to about 60 miles, below the sea-level surface.

Although this theory reduced materially the anomalies or differences between the theoretical and observed values of the force and direction of gravity, thus showing that a certain degree of compensation does exist, it has all along been held in India that the isostatic theory is only a partial explanation of observed results. It has been more successful in North America than in India in reducing anomalies and this may possibly indicate that, the former continent is geologically more stable. In India, however, the data accumulated seem clearly to point to the existence of deep-seated belts of excesses and deficiencies of density which have little relationship to surface geology or topography. The existence of what is probably the most marked of these belts was suggested by Sir Sidney Burrard some 30 years ago and called by him the Hidden Range, which runs across India slightly north of west through Jubbulpore. He derived this from a study of the deflections of the plumb line in Northern India and its existence becomes more and more certain as data are accumulated, not only of the direction but of the force of gravity. Such belts are inconsistent with any rigid and precise theory of isostasy such as that enunciated by Hayford which assumes that underlying densities vary only with surface heights and depths. Admittedly any theory as to the density of deep-seated masses must be put into a reasonably precise form to permit its effect on gravity to be computed with reasonable ease and one cannot condemn such a theory for its failure to explain all anomalies. The object should be to superimpose on the theory broad hypotheses which remove so much of the residual anomaly as to enable the remainder at any station to be attributed to such local variations of density as are acceptable to geologists. Clearly any anomaly of gravity at any one station can be removed by *some* assumption of local density but this assumption will affect neighbouring stations also and may increase the anomaly there; it may also be intrinsically impossible. Thus earlier attempts to explain by local conditions the great deficiencies of gravity in North Bihar resulted in the postulation of such a depth of light alluvium as could not be accepted.

If, however, broad assumptions of deep-seated variations of density do succeed in very materially reducing anomalies over large areas without increasing others, there is some certainty that they are correct. It is on these lines that Lt Colonel Glennie of the Survey of India and a Fellow of this Institute has been working for some years After allowing for a measure of isostasy and for the effect of the Hidden Chain, he finds that the residual anomalies in the force of gravity can be further materially reduced by postulating other continuous crests and troughs in the dense sub-crust. He calls these up-warps and down-warps and has propounded theories as to their origin which are being discussed. Charts showing these warps are published in the Geodetic Reports of the Survey of India. The study of these deep-seated features, which are believed to originate some 10 to 20 miles below the surface, will, it is hoped, throw some light on seismological problems and also on so different a matter as water-logging in irrigated and other areas.

The form of the geoid

Hitherto in referring to the figure or shape of the earth we have considered only a generalised figure which can be expressed in a reasonably simple mathematical form. Such a form is necessary for purposes of computation—to convert the measurements obtained by triangulation into latitude and longitude of the points fixed. By the middle of the eighteenth century it had become established that the actual shape of the sea-level surface of the earth, i.e. the geoid, could be more closely represented by a simple oblate spheroid than by a sphere. It is quite possible that an even closer approximation would be tri-axial ellipsoid but this would involve considerable loss of computational ease.

All countries which have executed any triangulation use an oblate spheroidal figure for computation of latitude and longitude but the elements of these spheroids are not always the same. In India, as I have mentioned, the spheroid used could definitely be improved upon although the labour involved in the change would be immense. But the enormous advantages that India has derived from the early execution of triangulation has vastly outweighed the disadvantage of using Everest's spheroid and we have no cause to reproach our predecessors for this use. Had they postponed the computation of the triangulation until the elements of the spheroid had been more accurately determined the main advantage of that early start would have been lost ? As it is, India has been free from the difficulties experienced by many countries which have carried out detached surveys without a rigid framework of triangulation. Our difficulties in fact have been relegated to the frontiers where they are clearly of less importance.

But whatever spheroid is used it is evident that it cannot absolutely represent the geoid. Excesses and deficiencies of matter and of density must distort the geoid from any purely mathematical form, and it is to these distortions, or as they are usually called separations, of the geoid from the assumed spheroid that considerable attention has been recently devoted in India.

From a study of the changes in the direction of gravity along a line of stations, it is possible to compute the changes in separation that will account for them. Given a sufficiency of such stations the separations can be displayed by contours on the spheroid thus clearly showing the shape of the actual geoid.

Charts showing these contours are published from time to time in the Geodetic Reports of the Survey of India and the shape of the geoid in Peninsular India appears now to be fairly well established. More data are needed in Burma and in the Himalaya in both of which areas the geoid seems to present unusual features. Whereas in Peninsular India the separation of the geoid from the International Spheroid, the figure adopted by the International Union of Geodesy and Geophysics, varies between about 35 feet above to 40 feet below, there are indications that in Southern Burma the geoid rises to something like 140 feet above the spheroid.

In spite of the forthcoming separation of Burma from India it is hoped that it may be possible to obtain further data in this area to elucidate this peculiar feature.

The Hidden Range is clearly shown by these geoidal contours which along a line through Sambalpur, Jubbulpore, Jodhpore, and Quetta indicate a crest of between 20 and 35 feet as compared with depressions of 40 feet near Gorakhpur to the north and 10 feet near Belgaum and Madras to the south.

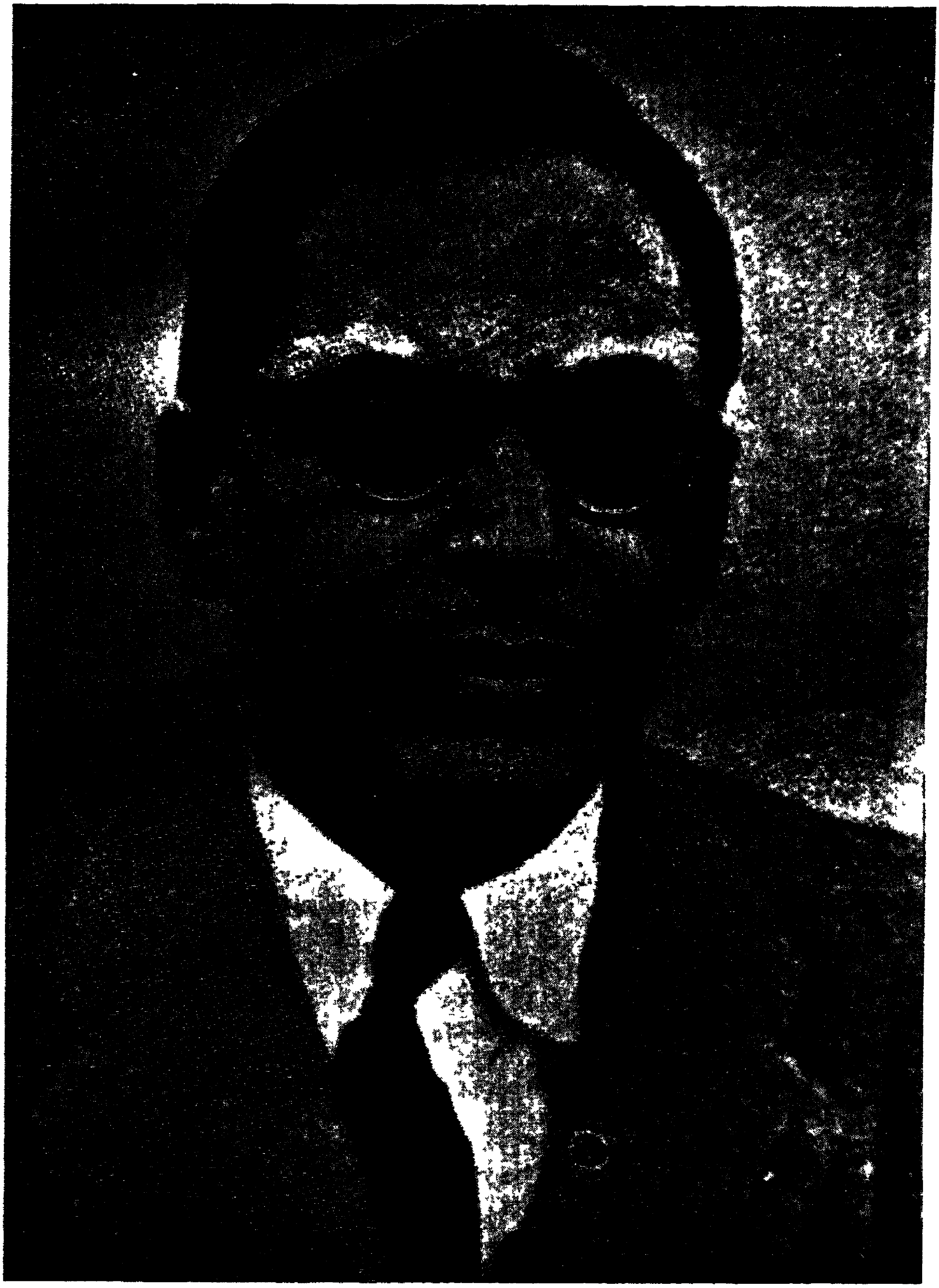
These geoidal contours have an intimate bearing on the heights of mountain peaks; these have been obtained by measurements of angles of elevations from distant points, and not, of course, by spirit levelling up to the summit. While the latter method gives true geoidal heights, since the levelling instrument at each station assumes a position parallel to the geoid, the former does not. After correcting for refraction the hieght obtained is above the geoid at the station of observation and would only represent the true geoidal height if both station and peak were on the same geoidal contour. As this is unlikely, the heights of all distant peaks require a correction at present unknown and this fact explains the reluctance of the Survey of India to change the well-known height of Mount Everest, 29,002 feet, to a more accurately calculated but non-geoidal value of 29,141.

If I may be permitted a word of departmental glorification, I will conclude by remarking that the geodetic activities of the Survey of India have been commended on many occasions by other countries and it is our hope that these activities will be continued for many years to come.

The study of geodesy is inevitably one involving much patience and persistence; results are hard to come by and their practical value is often doubted. Provided liaison is maintained with geology and geophysics, geodesy must lead to a better knowledge of the earth's structure and thus extend the discoveries of these sciences.

Professor Meghnad Saha, FNA*

(Foundation Fellow, President 1937-38)



Professor M N Saha was born on October 6, 1893 in Seoratali Distt, Dacca (now in Bangla Desh). He received his BSc degree from University of Calcutta in 1918. He was the Professor of Physics, University of Calcutta (1921-23 and 1938-53) and Professor and Head, Physics Department, Allahabad University and Honorary Director for the Institute of Nuclear Physics (now Saha Institute of Nuclear Physics) since its inception. He was a member of the Council of Scientific and Industrial Research and the Chairman of Council's Indian Calender Reform Committee; Member, University Education Commission; Member, National Planning Committee appointed by the Indian National Congress in 1938. He was a member of the Parliament from 1951. Professor Saha was the President, Indian Association for the Cultivation of Science, first Director of Laboratories of the Association; General President, Indian Science Congress (1934); first President, National Academy of Sciences (1932-34), Allahabad and the President, Royal Asiatic Society of Bengal (now the Asiatic Society) for 1944-46.

Professor Saha will always be remembered for his theory of thermal ionization and its application to the interpretation of stellar spectra in terms of the physical conditions prevailing in the stellar atmosphere. The equation that goes by his name was called the 'equation of the reaction isobar for ionization'. His researches in astrophysics and physics extended over a wide range of subjects. At one time or the other he worked on stellar spectra, thermal ionization, selective radiation pressure, spectroscopy, molecular dissociation, propagation of radio waves in the ionosphere, solar corona, radio emission from the sun, beta radio-activity, and the age of the rocks.

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*died in 1956.

THE PROBLEM OF THE INDIAN RIVERS

M N SAHA

(delivered at Calcutta, 1938)

1. Introduction

Indian Civilization mainly a River Valley Civilization:

You would probably like to know why I chose this particular subject for my address. India is vast enough to accommodate all the countries of Europe except Russia. The Indian population is still mainly concentrated in the valleys of the great rivers which intersect this continent. With a few exceptions, the great cities which are centres of industry, culture and administration are mostly to be found on the banks of the great rivers. If we go back in time and survey our past history, which can now be traced to 4,000 years before Christ, we shall find the same story; my own studies in the history of our country have confirmed me in the belief that even 200 years ago, there was a very scanty population in the country away from the banks of the great rivers.

Rivers essential for agricultural communities: In fact, this condition is not peculiar to India. Human civilization on this globe of ours has, since time immemorial, chiefly centered about rivers and river basins. Who can conceive of Egypt without the Nile, of ancient Sumer and Babylon without the Tigris and the Euphrates, and of China without the Hoang-ho (the Yellow River) and the Yangtsekiang? The early growth of settled human life in river basins is to be ascribed to the fact that rivers supplied the largest amount of needs of early societies which were mainly agricultural. They supplied them with the all-important water for drinking, bathing and other domestic uses, and for irrigating their fields. Rivers also formed the indispensable highway of communication before the discovery of the steam locomotive. Since rivers were so important to human life in its early stages of cultural development, convenient sites on them used to draw large populations, and such sites gradually grew to be great cities and capitals of mighty empires.

New Pathways of Human Activity: The rise of maritime civilizations like those of Greece (centred round the Aegean Sea) and of Rome (centred round the Mediterranean Sea), which was due to the extension of human activity away from riparian tracts, did not at all diminish the importance of rivers, though development of maritime activities gave rise to new centres of population like sea-ports. But these were generally clearing houses for the country products, which were produced in riparian tracts. In modern times, the growth of large-scale human activities and of the factory system has given birth to new centres of population which are in many cases away from rivers, but as the largest part of humanity has still to depend on agriculture, the rivers have not lost their importance to mankind. Moreover, in recent times, in addition to agriculture, novel use has been found for rivers. In the first place, for convenient and cheap transport of goods it has been found that no other method of communication can beat river transport. Secondly, some of the rivers, if properly harnessed, can supply electrical power which is all important for the development of industry and for other human needs in the present century.

2. Rivers need attention

Irrigation an ancient art: The importance of rivers may be gauged from such phrases as 'Egypt is the gift of the Nile'. But experience has also shown and this was also known to early human communities that rivers need attention. First of all, there is the annual cycle; during one season of the year the rivers are filled to the brim with water, sometimes overflow the banks, and inundate the fields. Then comes the lean period when they almost run dry. The ancient peoples found that if these phenomena could be controlled, the rivers could be made to do more good than if they were left to themselves. Out of these considerations rose the art of irrigation, one of the oldest ever practised by the human community.

Irrigation in ancient countries: Irrigation in different ways was practised on a stupendous scale in Egypt, Babylon, old China, as well as in India. In fact, the existence of the community depended upon the successful practice of irrigation. In Mesopotamia, the two rivers run through a desert country and only a small fringe of land, on either side of each river, is directly accessible to river water. But the ancient dwellers of the land, the Sumerians, five thousand years ago, cut canals from the rivers and irrigated their fields, which were away from the immediate reach of the rivers. In fact, but for the net-work of irrigation canals with which the whole land was intersected, very little of the country would have been habitable. Elaborate precautions were taken by the State for maintaining the canal system from the attacks of external enemies and from the harmful effect of internal quarrels. This magnificent canal system was the cause of the great prosperity of ancient Iraq, up to 1258 AD, when the Mongols under Hulagu Khan conquered the country, and systematically destroyed the canal system by blocking the mouths of canals and allowing them to fall into decay. Iraq, which up to the 13th century, contained the greatest cities of those times in the world (e.g. Baghdad) and was farfamed for its culture and prosperity, has never recovered from this catastrophe.

Modernization of Egyptian Irrigation: While the Babylonians practised perennial irrigation, the Egyptians practised 'Basin Irrigation' from time immemorial. They anxiously waited for the Nile to overflow its banks which it did with clocklike regularity, and then held up the water by throwing earthen mounds round their fields. In recent years, basin irrigation, which allowed only one crop to be grown in the year, has been converted to 'perennial irrigation' by the construction of the Assouan and other dams across the Nile. This has allowed Egypt to raise two to three crops in the year.

3. Irrigation in Ancient India

It is well known to every reader of history that irrigation has been practised from time immemorial in India, but owing to the vastness of the country the system practised has not been uniform as in Egypt or Babylon. During the troublesome days which ensued after the weakening of the Mughal dynasty about 1740 AD, and the re-establishment of settled rule under the British about 1800 AD, most of these ancient systems had fallen into decay, but sufficient had subsisted to enable us to form an idea of the way in which irrigation was practised in different parts of the country.

Diversity of Indian Irrigation in former times: In Modern India first of all, there are the arid areas of Sind and Southern Punjab which receive very little rainfall. Then come the precarious areas (areas of scanty rainfall) of the Punjab. Here, in ancient times, water was tapped by canals which were cut off from the banks of the rivers. The canals were filled with water only during floods. The western part of the Ganges valley does not suffer so much from defect of rainfall, but there are wide tracts in this part which are far away from the banks of the main rivers, and from which rainwater drains off quickly. The problem is to bring water to these areas by means of perennial canals. Southern India again presents a different aspect. In the centre it is a table-land, and the rain, which falls mostly within a short period, drains off quickly to the eastern sea. Ancient rulers held up the water by throwing dams across convenient sites on river courses, and thus creating reservoirs and artificial lakes from which water could be tapped for agricultural purpose whenever necessary. This is sometimes known as storage or tank irrigation. Besides these areas, we have in India the lower basins of the rivers, where the flow is perennial, and the deltaic regions, where in addition the rainfall is abnormally large. These areas present quite different problems, but to these I will refer later on.

The practical Indian Mind in ancient times: The successful practice of irrigation demands organization, settled government and scientific knowledge. Were ancient Indians capable of attacking the problem on scientific lines ? To the western world, India was known as a land which for all ages has been full of unpractical dreamers and philosophers. It was a mild shock to the West when, in 1909, an old Sanskrit manuscript, Kautilya's 'Arthasastra', was discovered.

This book reveals a different type of Indian mentality. Professor WE Clark, Head of the Department of Sanskrit at the Harvard University, says:

'The discovery in 1909 of the Kautilya-Arthasastra has opened up an entirely different world of life and thought in ancient India from that represented by the religious and philosophical literature of the Veda. Accounts of ancient Indian civilization based entirely on this religious literature are as misleading as would be accounts of early European civilization based entirely on the Church Fathers.

'The book deals with every phase of government as regulating all matters of worldly life—a government which was not dominated by the priesthood but which was highly practical and empirical. Sections are devoted to precious stones, ores, metallurgy and mining, roads, trade routes and irrigation, medicine, trees, plant and poisons, ships and shipping, cattle, horses, and elephants, chemistry, mechanical contrivances, and other technical matters. (*Legacy of India* by Garret.)

Irrigation under the Mauryan Emperors: We learn from this book that the great Mauryan Emperors, who in the third century before Christ ruled over a land bigger than the present British Indian Empire, maintained a regular department of irrigation and navigation. The officers looked after the maintenance of irrigation canals, levied taxes on water, and controlled navigation. An inscription found at Girnar in Kathiawar peninsula tells us that by the orders of the Emperor Asoka a great water storage tank called the Sudarshan lake was constructed by his Governor, the Persian Tusashpa, by throwing a masonry dam across a mountain pass. According to later inscriptions, it was twice repaired: Once by the Saka Satrap Rudradaman (150 AD) and then by the Gupta Emperor, Skandagupta (460 AD). Southern India is full of huge storage tanks used for irrigation which testify to the ancient rulers' solicitude for the storage and judicious use of water.

Another famous irrigation work was the Grand Anicut on the Cauvery river, where it begins to form a delta. This was constructed by the Hindu rulers of the First Century AD, and was in continuous use up to the 19th century, when it was repaired by Sir Arthur Cotton, the pioneer of large-scale irrigation in this country under the British régime.

The Gangetic Delta: The riparian area of India consists, besides the regions mentioned above, of the lower reaches of the rivers where they begin to form deltas. The physical condition of these areas and the life of the rivers are quite different from those in the upper sections. Up to Rajmahal, the Ganges receives only tributaries, but below it the river flows through soft soil and divides itself into a labyrinth of channels. The land is low and subject to inundations during the monsoon season. There is a great difference of opinion as to whether the ancient rulers tried at all to prevent these rivers from leaving their beds, finding out new channels and eroding villages and cities, as we find them doing now.

4. Long Period Changes in River Courses

The Punjab Rivers: I have given you an imperfect sketch of the usual regime of rivers in ancient times. Besides the periodic changes connected with seasons, certain long period changes in the course of rivers have been noticed by competent authorities, the cause of which is still hotly debated amongst Geologists, Surveyors and Historians. A comparison of the alignment of the Punjab rivers about two thousand years ago with the present shows that the Punjab rivers have a tendency to change their course and that they generally move west. There is a fight going on between the deserts and the river valleys. The desert is constantly encroaching on the rivers and pushing them to the North-West. Is it due to some deep-seated tectonic action whose influence is accumulative or has there been a change in the course of the monsoon tracks of rain-clouds? There can be no difference of opinion regarding the reality of these changes. The Archæological Department of the Government of India has found, besides Harappa and Mahenjodaro, a large number of cities buried under the sands of Sind and Rajputana. These cities could not have existed unless there was more plentiful supply of water in these regions 5,000 years ago than is to be found now. It has been surmised that the North-Western monsoon, which gives the Punjab a certain amount of rainfall during winter and is very beneficial for wheat cultivation, used formerly to have a more southerly course, and passed over Sind and Rajputana. It is further supposed that the rivers of the Eastern Punjab used formerly to unite in a powerful course and flow in a separate channel, parallel to the Indus, to the sea, thus giving Sind all the advantages of a land between the two rivers, the Indus on the west and the Saraswati on the east. It is surmised that the lower course of the Saraswati ran dry during Vedic times and its original course is marked by a dry channel. The other rivers have moved away from their courses generally to the west. What have been the causes of these changes in the courses of rivers which have taken place within historical times? My friend Mr Wadia of the Geological Survey of India who deals more extensively with these matters tells us that many of the rivers are more ancient than the land, and surmises that these changes are due to crustal movements.

It goes without saying that these changes cause great suffering to the population which is mainly dependent on agriculture. Are the changes controllable at all? In fact the work which has been done by the engineers in recent times in the Punjab may be summed up by saying that they have tried to restore the waterways which existed in former times and fight the tendency of the country to aridification.

The Ganges-Brahmaputra-System carries largest volume of water: When we turn to the deltas of the Ganges and the Brahmaputra we find that throughout historical periods, constant changes have been going on in the lower courses of these rivers, changes which have exerted a far-reaching influence on the economic and political condition of the countries through which they pass. The total length of the Ganges is only 1,500 miles wholly in India and that of the Brahmaputra is 1,800 miles of which 800 miles are in India. The length of the river courses may give one a false idea of the actual importance and the stupendousness of the geological changes caused by these rivers; for though the Ganges is rather short compared with the other great rivers like the Yangtsekiang in China or the Mississippi in the USA, careful measurements have shown that her peak discharge during the monsoon period exceeds that of the Mississippi and is seven times that of the Nile. The discharge of the Brahmaputra is about one and a half times greater than that of the Ganges.

These circumstances, combined with the fact that they flow over a comparatively small region, have made these rivers unique objects of interest.

Recent changes of water courses in the Ganges-Brahmaputra Delta: The courses of the Ganges and the Brahmaputra rivers over the lower reaches only 150 years ago, compared with their present courses, have undergone great changes. In fact, with respect to these lower deltaic regions, it can be said that the geography is changing markedly within the short period of a century. You find that some of the ancient water courses have entirely disappeared and new systems, which did not exist two hundred years ago, have come into existence. The Ganges and the Brahmaputra 200 years ago used to discharge their waters by two separate courses which were about 150 miles apart from each other. There was a third system of water courses between these two which, flowing through Northern Bengal, used to discharge its water independently into the sea or into one of these two rivers. But great changes occurred between 1787 and 1818, due to causes which are well known, and now the main streams of the Ganges and the Brahmaputra unite 200 miles inland. This has caused widespread changes in the topography and the economic life of these regions. These wide changes are characteristic of all the rivers in the whole of Bengal and in Assam and to a much lesser extent of the deltas of the Mahanadi river of Orissa. Are these changes partly due to some deep-seated forces or to the natural surface action of the rivers which, unable to carry their heavy load of silt, go on depositing it on their beds and banks, and are ultimately forced to seek new channels? Scientists will take a long time in answering such questions, but it is needless to say that these changes have caused great dislocation of human life —old cities have been eroded, prosperous country-areas have been washed away, swamps have been formed and regions once populous have been ravaged by malaria. Can these changes be controlled at all?

5. Problem of Deltaic Cities

Ruined Cities in Deltaic Areas: Besides causing widespread changes in rural areas, the deltaic rivers have played havoc with the ancient cities, results of centuries of patient and concentrated labour by ancient rulers and communities. Most of the ancient cities famous in tradition in this country and playing a great part in its political history grew on their banks, or on the banks of their tributaries. Nobody has yet given a full and consistent account of the causes leading to the rise and growth of these cities, nor has told us how far the phenomena of the growth and decay of states connected with them were due to the action of the rivers. We are usually apt to ascribe growth and decay of countries only to political causes, but a deeper probing into facts shows that this is not the whole story. A few examples will show. Ancient Pataliputra which was the capital city in India from the 6th century BC to about the 5th century AD—an interval of nearly a thousand years—owed its importance to its position as an important trade centre at the junction of 5 rivers (the Ganges, the Sone, the Ghogra, the Gandak and the Punpun, see *Science and Culture*, Vol 2) at a time when rivers were the main channels of communication. It now lies buried under the present city of Patna at a depth of 17 feet below the ground level. Its destruction was due, as authenticated historical tradition tells us, mostly to destructive floods. It appears that in the deltaic regions, the level of a city gradually goes down while that of the surrounding country rises, so protective bunds have to be constructed to keep the flood water out. But sometimes, particularly if the city is between two rivers, as was the case with Pataliputra, and there is simultaneous flood in the two rivers, these bunds give way, causing destructive floods and depositing thick layers of silt Modern excavations have shown that ancient Pataliputra used to be very often visited by floods, and ultimately disappeared under the silt deposit. It is quite probable that the disappearance of Magadhan supremacy after the 6th century AD in

Indian politics may be due to the destructive action of rivers on the chief cities of Magadha which the rulers were unable to gauge and control.

Destruction of Gaur: Those who have read the story of the discovery of the Indus Valley civilization in the sumptuous volumes published by the Archæological Survey of India are aware that many prosperous cities in the lower Indus Valley had to be deserted because they used to be very often visited by floods or the rivers changed their courses and deserted the cities. The whole Indus Valley is full of dead sand-buried cities along the old course of the Indus. Another menace to great cities on river banks is the possibility of the formation of unhealthy swamps in the neighbourhood which may give rise to catastrophic epidemics. An example is afforded by the story of the city of Gaur which from the 5th century AD to 1576 AD formed the capital of Eastern India. It was situated between two branches of the Ganges river, and another large tributary, the Mahananda, flowed near by. A very unhealthy swamp grew in its rear on account of changes in the river course and, possibly due to the lowering of the city level, the drains in the cities could not discharge the sewerage to the rivers properly. The result was the outbreak of an epidemic which swept away the majority of the population about the year 1575 and the vast city, which was estimated by the Portuguese merchants of the 16th century to contain a population of over two millions, now remains buried under an overgrowth of jungle.

Calcutta may share the fate of Pataliputra and Gaur: A similar fate seems to be slowly overtaking the present city of Calcutta, which is the successor of Pataliputra and Gaur as the premier city in Eastern India; its level has gone down within the two hundred years of its existence by about 2 to 4 feet below the level of the surrounding country and the drains from the city can no longer discharge their refuse matter to the surrounding river channels without pumping. The problem of Calcutta's drainage has been before the public for a long time but no satisfactory solution has been found. My friend, Mr S C Majumdar of the Irrigation Department, has dealt exhaustively with this problem. Will the citizens of Calcutta profit by his advice or allow their city to run to destruction like Pataliputra and Gaur? The case of Calcutta also confirms the belief that in deltaic regions the level of cities has a tendency slowly to go down, while that of the surrounding country gradually rises. The result is that city sewerage does not flow through the drains, unless artificial methods are undertaken, and the city gradually becomes unhealthy. In fact, as has been remarked, Calcutta may be buried in the near future in its own sewerage. These slow changes therefore deserve more study and attention than spectacular catastrophes like a flood. In fact, a look at the ruins of old cities in the deltaic regions is sure to produce the conviction that a satisfactory method of city-planning in such regions has yet to be evolved.

6. Modern Times

When the administration of this country devolved upon the British nearly two centuries ago, the task of maintaining all the ancient irrigation channels and storage tanks and keeping the rivers in order fell on their shoulders. From the very first the Government of India took the greatest amount of interest in irrigation work and it is estimated that a total capital of 150 crores of rupees has been invested in constructing new irrigation channels, building storage dams and repairing old works. According to the report of the Central Irrigation Board, about 30 million acres of land in India are being irrigated by these artificial canals which total nearly forty thousand miles in length. Of these, 22 millions are officially regarded as productive and the remaining 8 millions have been officially admitted to be unproductive. We have to consider whether the amount spent under irrigation has been sufficient, whether there is still room for improvement and expansion. What was the cause of a large percentage of works being unproductive?

Further Scope for extension of irrigation: On account of the peculiar orientation of the mountains and the seas, India is the recipient of a large amount of monsoon rainfall from the Bay of Bengal as well as from the Arabian Sea, within a short time. It is estimated that of the total rainfall on this continent, nearly 60 per cent gets evaporated, about 40 per cent passes through the river channels, and of this 40 per cent barely 6 to 8 per cent is utilised by the rural population for irrigating their fields. These figures alone show that in spite of large irrigation works already undertaken, there is still room for further expansion. The figure of 360 millions for the population of India may give the idea that India is over-populated, but the density of the population is only 200 per sq mile, which is much less than is the case in many other countries with less resources. A careful survey of the facts shows that there are large regions in India which still require extensive irrigation works for further development. If these regions can be developed, then probably a large part of the population can migrate from over-populated areas to these regions and thus relieve the existing congestion. A greater expansion of irrigation will also result in the production of more foodstuff and other economic products and give us a better standard of living. We have further to consider in what way the existing arrangements can be improved so that a greater return may be obtained to the Government on the invested capital.

Railway Bridges over Rivers: A new factor was added to the problems already existing on account of the need which was felt in constructing bridges over these rivers. About 80 years ago, railways began to be constructed in India and it was found necessary to span rivers by means of well-designed bridges capable of carrying heavy railway traffic. Now the design of these bridges requires that the engineer should have a very accurate knowledge of the life of the rivers, their maximum and minimum discharge and their variations throughout the year, the nature of the soil and the total amount of precipitation in the basins over which the rivers pass. They had also to find out how the construction of a bridge will obstruct free flow of water through the rivers and *affect the surrounding rural area.* A further factor has arisen in recent times owing to the necessity of supplying the country with cheap sources of electrical power. To this topic, however, we return later on.

7. Need of more River Physics Laboratories

The earlier engineers who were entrusted with these tasks treated the problem as they thought best and without meaning any disrespect to these early pioneers, it may be said that their actions have not always been very beneficial to rural interests. It is of course quite correct that the system of irrigation canals, which has been planned by the engineers within the last 100 years in the Punjab and the western parts of the United Provinces and parts of Madras and Bombay, has done immense good to the regions concerned and has brought prosperity and population to an otherwise waste area. But the same cannot be said of the deltaic regions of Bihar, Bengal and Orissa and parts of CP which contain most of the unproductive irrigation works. It appears that in the planning of canals, bridges and railway lines in these areas some very fundamental mistakes were committed. The case was very ably summarized by Sir Francis Spring, *the founder of River Physics in India.* While entrusted with the task of designing a bridge over the Ganges in Bengal, he went thoroughly into the problem and summarized the necessity of a River Physics Laboratory, in the following words:—

'As trustees of so fine a property as this—canals and railways, it might not unreasonably be expected that the State would see the importance of devoting a comparatively small annual appropriation to original research, on lines likely to be productive of a good return for the expenditure, in the form either of reduction in the first cost of its public works or of their safety and their economical up-keep when built. *Heretofore there has been no pretence of organizing any such research* in connection with the engineering of the canals and railways of India. *Engineers have gone on blundering, benefiting, rather by chance than by design, by the experience of their predecessors, and each considering himself lucky if he escapes disaster at the hands of the tremendous forces of nature—amongst which some of the most potent for good or evil are the great rivers—with which he has to struggle.* Until quite recently there has been practically no encouragement, and indeed at times there has been discouragement, to men to publish their experiences. And so, in spite of having perhaps as fine a body of scientific engineers as any country, not excluding France, has in its employment, and in spite of this body of public servants having carried out daring and extensive works of a certain character, chiefly, in connection with the great Indian rivers, on a scale unparalleled elsewhere, the State possesses the most meagre record of the history of the works carried out so successfully by its employees. In putting the chapters of this book (*River Training and Control* by Sir Francis Spring) together, the author found extreme difficulty in ascertaining what had been done, what difficulties had been encountered, and how these difficulties had been surmounted, and it has needed the expenditure of nearly a year of research to enable him to offer to the Government of India the advice, contained in the foregoing chapters, in regard to one limited phase of the engineering of great rivers. Time will show the value of that advice, and doubtless further experience will modify the practice recommended. But meanwhile *the author would urge on the Government the importance, from a mere money point of view, of insisting on the maintenance of an intelligent record of the history of such works as those dealt with in the foregoing chapters.*'

The Consequence of lack of Organization

'With regard to the physics of long reaches of the great rivers, the author is not in so good a position to speak. His special experience has been gained rather on short lengths of such rivers in contiguity to his works. In view of his practical inability to regulate the flow of great lengths of such rivers he has viewed the inimical consequences of the irregularities of their flow, in the form of deep and dangerous scour, as requiring to be fought by sheer irresistible force rather than by coaxing This necessarily must be the attitude of the engineer in charge of great bridges, and perhaps to a lesser extent of those in charge of great irrigation weirs. But *they ought not, for that reason, nor ought the State, to lose sight of the importance of endeavouring, by consistent, logical and well-organized research, to learn something more definite than is now known about the physics of long reaches of rivers.* A perusal of chapters III and XXI, as well as of Mr R A Molloy's Technical Section paper No 118, will suffice to show how blindly, heretofore, in the interests of the residents on their banks, men have been fighting against the ill-will of some of the great rivers; whether on behalf of the maintenance of levees[1] whereby devastating floods are excluded from great inhabited areas; or for the conservation of the heads of inundation canals on whose integrity the welfare of many thousands of people is dependent; or *in the interests of riparian cities whose obliteration would be a blot on the administration of civilized and intelligent rulers. It is difficult to avoid the conclusion, after perusal of chapter XXI, that for lack of adequate knowledge, the engineers concerned with the interests of the inhabitants of the valley of the Indus have been obliged to work more or less in the dark in their fight with that river, and to make matters worse it has constantly happened that, owing to the climate, to the exigencies of public service, no sooner does one engineer get some small inkling of the tricks than he is replaced by one with all his*

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[1] This is a word of French origin, which is used in the USA to denote embankments.

experience to gain; and in six months he, in turn, is replaced by somebody else whose experience of the river has perhaps been limited to crossing it. How, under so haphazard a system, anything gets done at all is a marvel; and instead of being surprised at £100,000 worth of work having been wiped out, the State may congratulate itself if the loss is not double. However there is always the satisfaction, in the case of such expenditure as that dealt with in chapter XXI, that the whole of the money has remained in the country, and that if the taxpayer takes money out of his coat pocket only to put it into his waistcoat pocket he can always pick it out again, or its equivalent.'

Suggestion for the appointment of a River Commission

[1]*The appointment, for say 10 years, of a River Commission not merely for the Indus, but for the organized study of the physics of great alluvial rivers generally, would be a service to civilization and an act worthy of a great State.* The Mississippi Commission have done a great deal, but their experience is not to any great extent applicable to Indian conditions. The experience of the engineers of the Rhone and the Danube and other European rivers, though valuable in its way, is even less applicable to India than that gained on the Mississippi. Mr R A Molloy's attempt at a theory, as summarized very inadequately in chapter III, is the first that can be characterized as a scientific generalization of the river problem that the author has heard of in India. And even this is based on inadequate data, picked up anyhow, amidst the multifarious duties falling to the engineer to a system of inundation canals. There is need for a thoroughly scientific location, and for the automatic reading, of gauges at hundreds of places, for several years, along great lengths, selected with care and knowledge, of several of the great Indian rivers, also of some systematization of the surveys which usually are undertaken on these rivers, and of the making of fresh surveys specially designed to elucidate facts, also of an organized system of soundings and sections. The engineers in charge of the work must steadily keep in view the ultimate object of it, and must not make a survey merely for *the sake of a section. The object in view will be: To present to the scientific world, and especially to the engineering world, and more particularly to the engineers of structures in India that are subject to fury at the hands of the great alluvial rivers, such an explanation of the probable action of these rivers, under various circumstances, as will allow of such action being anticipated; and especially, to enable the engineer to utilize fully his knowledge of the rivers,* so that he may make a servant of it, instead of being as it is now very often the case, his master. There can be no doubt at least from the author's point of view—*that more money has been wasted, for want of just such knowledge as a River Commission might provide, than would have sufficed to pay the entire cost of it many times over.* Certainly, so far as training works in connection with bridges are concerned, in rivers of the class with which the author has chiefly concerned himself, most engineers responsible for such works would probably admit that whether they spent money unnecessarily as an insurance against their inevitable lack of scientific data, or that they were unduly economical, with either disaster, or heavy annual recurring expenditure in after-years, as the result. Thus looked on from the lowest or merely commercial standpoint, the establishment of such a Commission ought to be highly remunerative.'

The Government very slow to adopt Spring's advice: Unfortunately the sound advice given by Spring has not been acted on very quickly by the Governments. But Sir F Spring was not the only man who voiced this opinion. Mr Reakes, who was entrusted by the Bengal Government with the task of surveying the Nadia Rivers, was so puzzled by the problem of river changes in Bengal, that he made practically the same recommendations as Sir Francis But the Bengal Government has shown no intention of profiting by these advices. It is only the Punjab Government which profited by the advice given by Spring, and has created, within the last 10 years, a well-equipped research laboratory, the staff of which contains, not only irrigation engineers, but also physicists, statisticians, mathematicians and people belonging to other branches of science, who can render sufficient help in tackling the problems of irrigation and of river control. The Central Government maintains a River Physics Laboratory near Poona, where experiments on the models of the rivers have been carried on under the able guidance of Mr Inglis for about 10 years, and many problems submitted by engineers from different parts of India have been tackled there. But considering the vast size of the country, the diversity of the problems in the different regions, the number of laboratories is extremely small and the equipment of those laboratories which have been constructed is not sufficient. Even in the Punjab, the work done is not considered sufficient. Dr Mackenzie-Taylor, Director of the Irrigation Research Laboratory of the Punjab, says:

'Though India is a country of mighty rivers, very little has been done here by way of experiments in the laboratories on river models. Only in recent years have some experiments been conducted at the Hydrodynamic Research Station at Khadakvasla near Poona and at the Punjab Irrigation Research Institute, Lahore.'

The provinces of the lower Ganges valley which, more than any other provinces, require a thorough field study of their rivers, as well as investigations on river-models in laboratories prior to any work being undertaken, have hitherto shown complete indifference to the proposals of having hydraulic research laboratories. All the same, blundering projects have been pushed through, which have wasted crores of the taxpayers' money. A small fragment of these sums, spent on the establishment and proper equipment of hydraulic research laboratories, would have been of immense benefit to the country.

8. Problems of the Lower Ganges Delta

I will illustrate my case by special reference to Bihar and Bengal. I have already told you that the problems in these two provinces are entirely different from those of the semi-arid areas of the Punjab and the upper Ganges valley, yet in the past works have been pushed on in these provinces which ought never to have been undertaken. The main problem is not one of supply of water in the same way as to the thirsty areas of the Punjab or of the Western UP, but entirely different. These provinces have a copious rainfall, the peasantry here very seldom require water for irrigating their fields; the problem here is to get rid of the excess water as quickly as possible, prevent the rivers from changing their courses, minimize the effect of destructive floods, and prevent the formation of unhealthy marshes and swamps. This can be done only by a judicious control of the activities of the rivers or by river-training. Unfortunately the engineers who were entrusted with the planning of bridges and embankments for the protection of railways in these provinces, and also with the charge of irrigation, were not sufficiently familiar with the peculiar conditions of these provinces and used in the solution of their tasks their knowledge of irrigation obtained in other provinces. This has been mainly responsible for the large amount of wastage in irrigation which is marked by the department as unproductive. But it has done worse things than that. The people of Bengal have always clamoured that the railway embankment has ruined the Burdwan division. It changed the courses of rivers in this division and deprived the land of the fertilizing silt. The Burdwan division became therby a victim to malaria which, between 1860 and 1870, carried off nearly half of her population.

Central Bengal, a country of dead rivers: The same is true of Central Bengal but here the ravages are due to the change in the course of the river. The Ganges used formerly to discharge its water through the western branches but now the mouths of these channels have been silted up and the main mass of water flows through the easternmost channel. This has made Central Bengal a land of dead rivers and swamps and a prey to malaria. The problems of Bengal have been so very ably treated by Mr S C Majumdar that it is useless for me to go into great detail. By his careful survey and analysis he has also pointed out the way in which the rural conditions can be improved. He has clearly shown that this can be done only by the undertaking of a large amount of engineering work aimed at controlling the rivers judiciously. But I submit that satisfactory results can be achieved only if the problem is studied very carefully before any work is undertaken. The need here is for studying the rivers intimately. We must take observations for a number of years regarding the flow of rivers, variation of the flow throughout the year, how they depend upon the precipitation in basins, how they deposit their burden of silt and what is the action of the silt on the fertility of the soil. We have to undertake fundamental experiments, for as Dr N K Bose and Mr Lacey will tell you there are many fundamental problems in river physics which still await solution. They are still the subject of careful study by distinguished workers. It is necessary to have in each region a River Physics Laboratory where the fundamental problems will be handled by a number of expert pure scientists. In addition there is need for a properly equipped field survey department which will survey the contour and geological formation, the carrying capacity of the river-beds and ultimately, whenever any constructional work is proposed, this should be studied by a laboratory model carefully. After all these studies are completed actual work should be undertaken.

9. Cheap Electrical Power

Within the last fifty years, another use has been found for running water which is as important as irrigation and navigation, viz. generation of cheap electrical power out of the energy of running water. This is a subject which is just beginning in India, but its importance has not been properly realized. I wish therefore to dwell at some length on this point.

Analysis of Professions in India: Everybody knows that India is an agricultural country. According to the Census Report of 1931, 66% of the Indian population is engaged in agriculture, i e. are peasants, i.e. they have to spend their life in raising food. Of the remaining 34%, only 11% are city-dwellers, i.e. engaged in industries and other professions. The remaining 23% are either village artisans, merchants, landlords, or belong to other professions mainly dependent on a rural economy.

India, a land of poverty-stricken peasants: Everyone will admit that the distribution of the population according to professions reveals a very unhealthy state of affairs. In no other country of the world, excepting such backward ones as China, is there such a large proportion of peasants. And do these peasants enjoy a good living? A few huts, mostly without doors or windows, a few mats and rags, a few half-starved animals, hunger, debt, and frequent disease, —this is all they have to enjoy !

Agricultural Improvement—no solution of the poverty problem: There is a widespread desire for improving the lot of peasants and to raise the general standard of living. But how can this be achieved? Not by an exodus of the townsmen to the villages as advocated by certain persons distracted by middle class unemployment; for that will merely increase the pressure on the overcongested rural area and multiply misery. Greater efficiency in agricultural methods, which is certainly desirable, may give us more and cheaper food, and other necessities of life obtained from agriculture (like cotton), but it can never touch even the fringe of the poverty and unemployment problem. For greater efficiency amounts to the fact that the same production in agriculture can be effected by half the present number. At present, the proportion of food-gatherers is

66%. They produce food materials and other products by the most primitive methods. If improved scientific methods are adopted, larger amounts, more than sufficient for the whole nation, can be produced by 30% of the population. This will render about 36% of the peasant population unemployed. This added to the already existing middle class unemployment will render matters worse.

Industrialization the only solution of the poverty problem: If we analyse the widespread public sentiment for better living, what do we find? Everybody of course wants his food supply to be insured, but this is the least part of his demands. He wants to be better clothed and better housed; wants to get a better education for himself and his family, more rest from work, freedom from drudgery and greater enjoyment of life. Analysing this sentiment, we find that if these needs are to be satisfied, the quantity of industrial products has to be increased ten to twenty times its present level; all these works have to be organized, and a large proportion of the village population is to be diverted from the task of food-raising to industrial work. In fact, the only way to improve the villages is by drafting more villagers to the cities, and by creating a larger number of cities based on industries.

10. India's fitness to be industrialized

India has sufficient resources for efficient industrialization: But all countries, even if they want to have a better living, as is reached to-day by some European countries, cannot do so on account of their intrinsic poverty in natural resources. The source of potential wealth to-day is not merely good agricultural land of all varieties, capable of yielding all kinds of food and other economic products, but also mines, capable of yielding minerals useful to man, and sources of power (coal, oil, peat and other fuel, water power). A recent writer in the *East Indian Review*, analysing the conditions of the world, finds that only three countries in the world satisfy these conditions, viz, USA, Soviet Russia, and India. He traces much of the present political troubles of the world to poor resources possessed by many ambitious nations. Italy, for example, has almost no coal or iron, and very little mineral resources. Hence her desire to seize other undeveloped lands, otherwise she cannot reach the modern standard of better living. Japan is almost in an identical condition, and is further handicapped in having poor agricultural land as the country is not suited for the production of any agricultural stuff other than rice and mulberry. Cotton and oil-seeds cannot be grown on her soil. Hence her desire to seize parts of China. According to this author, China, even if she were not pestered by foreign aggressors, and could solve her own internal problems, can never attain the level of the USA or the future Russia, because her mineral resources are poor. Only India possesses all kinds of resources in abundance; she continues to be poor, only because these resources have not been developed and industrial work has not been properly planned and organized.

How to organize production and distribution of commodities essential for civilized human life: The wealth of a people is neither a gift of the heavens, nor a gift of nature. The people have to create wealth by organized labour. The more the output of work by a country, the richer it is and the higher the standard of living reached. Probably, most of our countrymen have no idea that the total work output by the average Indian is twenty times less than that of the average American and European. In previous epochs of history, all the work used to be done by human power, or animal power. But at the present time, most work is done by steam-engines, oil engines or electricity. Let us compare quantitatively the work output per man in Norway and in India. I am taking Norway because there all power is electrical and can be easily calculated.

The League of Nations' Year-book tells us that the average Norwegian consumes

1,600 units of energy per capita in the year, which is mostly derived from the harnessing of her rivers and waterfalls.

As we shall see presently, the man power and animal power probably does not contribute more than 80 units per year. Hence the total output of energy per capita in a civilized State is about 1,700 units. With less output, the standard of living would go down.

India produces 20 times less work per capita than European countries: Let us see the average output per Indian. The electrical energy per capita in this country is only 7. Steam and oil power will not amount to more than 10. Let us now calculate the work done by man and animal. A labourer working for eight hours daily produces only 6/10 units and in a year of 300 working days he does not produce more than 180 units. But only one-third of men and women are active. Hence the average output per year per capita is only 60 units. Taking the work done by animal power to be 10, the total output of work per capita per year is only 90 units. This is nearly twenty times less than the work output per European, and about 6 to 8 times less than that of the Japanese.

To use figurative language: The average European has 20 slaves constantly working for him while the Indian has mostly to depend upon himself. The slaves which the European calls to his aid are provided from the exploitation of the power resources of his country. Such resources though they exist in India have not been developed and profitably utilized. This is the root cause of poverty in India.

Not only have the power resources not been developed, but the available power is extremely dear. This is one of the main causes of India's backwardness in industrialization.

Dearness of Power: How much India is handicapped in this respect may be gathered from the fact that the price of power in this country for the greater part of the country is four times that in England and Japan, except probably for steam power, which is not suited for many industries, and is not available in all parts of the country. Thus the cheapest elecrical power at Calcutta costs ½ anna—·57*d*, the average price of power is about —2 annas—2·2*d*; in London electricity 1*d* and at Allahabad if bought in bulk can be had for ¼*d* per unit.

High Price of Power: The price of petrol varies from Re 1—2 as. to Re 1-10 as., while the price in England and Japan is about 6 annas. Most of the extra cost is due to customs duty and railway freight. The landing cost is only about 4 annas. On account of the great cost of petrol, Otto engines are very expensive to work in India.

It is on account of the high price of power that industrial enterprise has so far been confined to cities like Calcutta which are near coal mines, or Bombay which possesses, thanks to the enterprise of the Tatas, cheap hydroelectric power. Other areas cannot develop unless they are provided with cheap power.

11. How to develop power resources

India rich in Power Resources: But it may be asked, are there sufficient power resources in India? Like some other countries in the world, India may be intrinsically poor in power resources. Let us consider this problem in detail. The chief power resources are:—Coal, water power, oil, shale, and other fuel (peat, wood, bagasse, power alcohol and vegetable oils).

Coal resources are present only in certain parts of Bengal, Bihar, Orissa and Assam, in other words in Eastern India. Other parts of India are extremely deficient in coal, or do not possess it at all. If India wants to be industrialized, it must develop its available water power. Let us see how much has been done in this connection.

The water power resources of India have

not yet been adequately surveyed except in a few isolated regions. The work which was started under Meares in 1919 was unfortunately stopped for some unknown reason. According to this authority, the total resources amount to about 20 million kilowatts, but this may probably be a gross underestimate, as in the case of Soviet Russia.

Necessity for development of Water Power: The total power which has so far been developed amounts to about half a million kilowatts installed. Of these, ·3 million kilowatts or about 60% is due to an Indian State (Mysore) and private (mostly Tata's) enterprise, and the rest is due to the enterprise of the Provincial Governments. These figures show that only 2·5% of India's hydroelectric power resources has been developed.

The efficiency of the undertakings which have so far been developed leaves much to be desired.

The earliest large project in India is the Sivasamudram Hydroelectric Works in Mysore which owed its genesis to the far-sighted vision of Dewan Seshadri Iyer of Mysore. It has developed nearly 50,000 kilowatts, and the cost of installation has been nearly Rs 500 per kilowatt installed. The three Tata projects near Bombay cost about Rs 500-600 per kilowatt installed, inclusive of transmission lines.

Bad beginning in hydroelectric development: The upper reaches of the Indus and the Ganges valley offer unique opportunities for hydroelectric development and there is great need for such development if these areas are to be industrialized, as there exists neither coal nor petrol in sufficient quantity in these parts. But the results obtained so far have been rather discouraging. The Mundi Scheme in the Punjab, which was launched under Government initiative against the almost unanimous opposition of the people's representatives, cost nearly Rs 3,000 per kilowatt installed; this holds the world's record for dearness, and is about 10 times dearer than the average cost of installation of plants of this size in Europe and America. The Western Ganges Hydroelectric Scheme which appears to have caught the imagination of a large majority of our countrymen cost Rs 1,200 per kilowatt installed. This holds the second highest record for dearness, and yet such a project has been hailed as a great work by a section of our countrymen.

But the reader may ask, what have rivers to do with electrification schemes? As has been pointed out, electrical power in most parts of India can be obtained only from water power, hence it is obvious that before an expensive scheme is launched (and all hydroelectric schemes are expensive), extensive preliminary studies are to be made. These include a summary of the water power resources showing the variation of discharge of rivers, possibility of erecting storage reservoirs, finding out the best site, and further economic survey with a view to utilization of all the power developed. Even when a site has been chosen, extensive laboratory experiments should be carried out with the aid of models on the proposed dams, weirs, reservoirs, etc. before any work is actually undertaken. If one goes critically into the history of the unsuccessful works just mentioned, he will find that the root cause of failure was that schemes were launched by enthusiasts (in many cases by amateurs in hydroelectric engineering) without adequate surveys and preliminary experiments. In the Mundi Scheme, nearly 6 crores of rupees were wasted before it was discovered that the river from which power was to be tapped almost ran dry during the hot season. If a small part of this money was spent on adequate surveys, and preliminary laboratory researches, probably the Government would have received a handsome return on their investment, most part of which has now to be written off as unproductive.

Example of Soviet Russia: Let us contrast the procedure adopted in this country with that in Soviet Russia. Before the Great War, Russia was no better than India. She was mainly an agricultural land, 70% of the population were peasants, almost as poor and ragged as the present-day peasants in India. Industries were in a backward state, and power was undeveloped and considered a luxury. The total amount of electrical energy per capita was only 15 units which, in 1919, owing to the ravages of the War and the Revolution fell to about 5 units. She was without knowledge of her power resources, without experts and technicians. It was during these dark days that Russia, under the influence of Lenin, started schemes for planned electrification for the whole country which was part of the larger scheme of complete industrialization. Now within a short period of 16 years, Russia is producing nearly 300 units per capita. Her production of electricity in 1937 exceeded that of any other country in the world, excepting the USA, and if she can complete all her schemes, she will soon overtake the USA. Needless to add that thanks to this intense electrification, Russia has passed from an agricultural state to an industrial one, and now 70% of her population are reckoned as industrial workers. She is on a fair way to the solution of the problems of poverty, disease and famine which perpetually haunted her peasant population of 70% before the Revolution.

There is a great prejudice in this country as well as in Europe against everything Russian, but not being a politician I am not interested in their political theories or the execution of those theories. What strikes me as a scientific man is the extraordinary use they have made of modern scientific knowledge in solving their problems of poverty and want, and the extremely judicious and businesslike fashion in which they proceeded with their schemes and co-ordinated the labours of economists and technicians. I have on my table a book written for the World Power Conference on the Electrification of Russia. We learn from this book that when the supreme council of the Soviets adopted Lenin's resolution for the electrification of the country, it was the USSR Academy of Sciences and not a committee of bureaucrats which was requested to give a plan. Under the guidance of the Academician Professor Krzhizhanovski the following plans were adopted: (1) Immediate establishment of a Power Research Institute for undertaking a survey of the existing power resources, coal, peat, oil, shale, and above all of water power, in the USSR. (2) Establishment of an extensive scheme of hydrological survey—so far the USSR possesses 5,200 hydrological stations of all classes, for surveying the discharge of rivers at different points, their variation throughout the year, etc. (3) Establishment of a number of River Physics Laboratories at Tashkent, Moscow, and Leningrad and other centres where researches with laboratory models of projected weirs, dams, embankments, canals are carried out before any work is actually undertaken. (4) Establishment of a comprehensive scheme for training an army of technicians in Russia.

It goes without saying that the plan adopted by Russia is the correct one. A scheme is known by its fruits. Russia now instals every year power-stations of millions of kilowatts capacity instead of thousands. The energy produced is utilized by the properly planned industries, and in transport, and only a small percentage is utilized in agriculture. Thus within the last sixteen years, the nation has passed from a community of half-starved peasants to well-fed and well-clad industrial workers.

12. Conclusion

Before I conclude, let me place before you a challenging statement from a very interesting book by Dr Vera Anstey. In her 'Economic Development of India' (1936) she says:

'Here is a country of ancient civilization, with rich and varied resources, that has been in intimate contact with the most materially advanced countries of the West, but which is still essentially mediaeval

> in outlook, and organization, and which is a byword throughout the world for the poverty of its people.'

Then she quotes Mr M L Darling:
'The most interesting thing about India is that her soil is rich and her people are poor' and asks herself:

> 'Can India be called "Mediaeval" when it is organized under a modern form of constitutional Government, possesses a great system of mechanical transportation, a unique system of irrigation, no less than seventeen modern Universities, and has several large-scale industries producing with the most up-to-date machines that have yet been invented?

The answer, however galling to our pride, must be that in point of poverty, ignorance and disease, India of today can only be classed with China and Abyssinia, countries which are still steeped in mediævalism, and have paid the price for continuing mediævalism.

If we desire to fight successfully the scourge of poverty and want from which 90% of our countrymen are suffering, if we wish to remodel our society and renew the springs of our civilization and culture, and lay the foundations of a strong and progressive national life, we must make the fullest use of the power which a knowledge of Nature has given us. We must rebuild our economic system by utilizing the resources of our land, harnessing the energy of our rivers, prospecting for the riches hidden under the bowels of the earth, reclaiming deserts and swamps, conquering the barriers of distance and, above all, we must mould anew the nature of man in both its individual and social aspects, so that a richer, more harmonious and happier race may people this great and ancient land of ours. Towards the realization of this ideal, we must adapt ourselves to the new philosophy of life and train the coming generations for the service of the community in scientific studies and research.

SOLAR CONTROL OF THE ATMOSPHERE

M N Saha

(delivered at Lahore, 1939)

Introduction

I wish to tell you about the Solar Control of the Atmosphere. It is a matter of common knowledge that weather and climate, so important to human life, are completely controlled by the Sun. But our troubles begin when we attempt to have precise knowledge of the way in which this control operates. This has been an eternal problem with mankind. In ancient communities, there was a profession of Weather Prophets whose duty it was to foretell and, if possible, to control with magic, the weather. Such was the importance attached to the office that a successful rain-maker was very often asked to rule over the tribe. But when he failed, as he must have done frequently, he was sacrificed before the altar of the tribal god. In later times, the office was transferred to Astrologers who are still found in many parts of the world issuing weather forecasts for the year. Scientific study of weather and climate dates from the time of the discovery of the barometer by Torricelli, but from the very nature of things, early meteorology could not find out a Newton, and it was realized that meteorological data must be patiently collected, classified and analyzed by a world-wide survey, before we can have any inkling of the secrets of the very puzzling complex of phenomena presented by Meteorology. For this purpose, Meteorological Surveys have been organized almost by every State, and a system of short and long range forecasting has been undertaken. But short range forecasting owes, whatever success it can claim, more to powers of quick transmission of news rendered possible by modern discoveries in Physics than to any profound insight into the nature of the problems involved. But what would really benefit mankind is a system of successful long range forecasting six months or at least 10 to 15 days ahead. It is well known that the meteorologist has not succeeded in this task because the problems confronting him are too intricate and he has to deal with a large number of complex factors. I must not, however, forget to mention that within recent years, Franz Baur in Germany, and Multanovsky in Russia have developed methods for medium-range forecasting which have attained a certain amount of success. Their methods are based on combination of Synoptics and Statistics, and in Franz Baur's method, atmospheric conditions at a height of 5 kms at any time are supposed to control ground weather for the next 10 days. But no physical basis has yet been found why this should be the case.

It would probably be considered strange that in spite of the great accretion in our knowledge of physics, and in spite of the large number of qualified men employed in the study of meteorology, we should be forced to admit that success still eludes us. Probably one of the reasons is, as one great Physicist once told the present writer, that meteorology has not yet engaged the attention of a Newton, or as I may add of a Bohr or Heisenberg. Another reason appears to me that the meteorologists long confined themselves to ground phenomena and neglected the Upper Regions. It is true, that in recent years, upper air surveys have been receiving greater and greater attention. There are the spectacular stratospheric flights, exploration of the Upper Atmosphere by Radio-meteorographs—instruments carried in balloons which signal by radio weather conditions up to heights of 30 kms.

It is usually thought that ground weather is controlled less by the interaction of solar radiation on the atmospheric gases of the sun, than by the direct heating of the surface of the earth by the solar rays. But in the light of the discovery of the stratospheric region towards the end of the last century, and plausible influence of upper air movements on ground weather possibly the upper air studies have been too much neglected. In view of the prospective use of the stratosphere for air-travel, and the use of the still higher region for radio propagation, probably the need will soon be felt for a better knowledge of not only the stratosphere, but also of the still higher regions. Here photochemical action of solar radiation on the atmospheric gases plays the chief part. For studying these reactions, we must have a good knowledge of the radiative properties of the sun, but it is not usually realized how defective and imperfect our knowledge in this respect is. We have not, as yet, a comprehensive knowledge of the reactions produced by sunlight on the constituents of our atmosphere.

The Ozone Screen

The sun is regarded usually as a black body at 6000°K. But it has been known for a long time that this is only a first approximation. We find several very glaring deviations from the black body curve. Even after allowing for loss by absorption and scattering by the atmospheric constituents, we find that the emissivity of the sun cannot be referred to any definite temperature. Our knowledge is particularly defective in the ultra-violet region because the solar spectrum is abruptly cut off below λ 2900 Å. This was regarded as a great puzzle by the earlier workers. In 1881 Hartley showed that this abrupt termination of the solar spectrum is due to a small amount of ozone present in the atmosphere. Ozone is not distributed according to the laws of hydrostatics as in the case of the other gases, but was shown by Fabry and Buisson in 1913 to be localized in the upper regions. Interest has now shifted to an actual determination of the total amount of ozone in the atmosphere, its variation with altitude, season of the year and the time of the day. A successful carrying out of the programme involves a world-wide survey which has been initiated by Dobson, Gotz and Meetham, and is being carried out in different countries of the world. But what is most surprising is the extremely small amount of ozone which is responsible for the complete obliteration of the whole solar spectrum between λ2900 Å and λ 2200 Å. The amount is found to be not more than ·3 cm. of the gas at NTP spread over the atmospheric layer from 20 km to 50 km, and having a maximum density at about 30 km, but the amount undergoes variations which are clearly connected with meteorological conditions. The ozone itself is not an original constituent in the sense that O_2 or N_2 are, as in that case, instead of occurring at a height it would have settled down at the bottom, but this is not the case; it has been found that O_3 is produced by the photochemical action of sunlight on the oxygen of the atmosphere in a way which is not yet completely elucidated. But this small amount is sufficient to cut off the whole amount of ultra-violet light below λ 3000 Å. In a sense this is lucky, as otherwise sunlight would have had a very harmful action on living matter on the earth and probably would have made life very trying, if not impossible.

Above the Ozone Screen

Suppose we can push above the ozone screen. What would the spectrum of the sun be like? Such a feat does not appear to be quite impossible. In fact, Regener, to whom the world is indebted for the cosmic ray exploration of the Upper Atmosphere, sent up in his sounding balloon an automatically working spectrograph to a height of about 30 km and secured the spectrum of the sun from this height. It was found that the ultra-violet limit is slightly pushed down and a much smaller time is needed to secure the solar spectrum at λ 2900 Å. It is quite possible, as was suggested by the present author in a Harvard Bulletin three years ago, that in the future automatically working quartz or fluorite spectrographs would be regularly sent up in balloons up to a height of 50 km and the spectrum of the sun below λ 3000 Å would be secured. Such work will greatly add to our knowledge of the radiation from the sun in this region, which is subject to greater fluctuations with disturbances on the sun than the spectral region directly accessible, and thus entirely set at rest speculation regarding solar radiation in this otherwise inaccessible region.

Aurora: Active Sun

But as long as such direct evidences are not forthcoming, it will be necessary for us to obtain conclusions from indirect sources These are the phenomena which are observed in the part of the atmosphere above the ozonosphere. This region does not contain more than 2 per cent of the total mass of the atmosphere, but it is found to be as much crowded with interesting phenomena, nay even more than the 98% down below. Amongst these phenomena, the best known is the Aurora or the polar lights which are familiar to the dwellers of the northern regions which suffer from a long winter night. The sky is frequently illuminated in these regions by brilliant flashes of light and these, naturally enough, have engaged the attention of generations of Scandinavian physicists, Birkeland in the early part of this century, Stormer, Vegard, Rosseland and their pupils at the present times. Even before systematic studies were started it was found that the occurrence of these northern lights was subject to solar control. It was found that the brilliancy and frequency of these auroral lights were not constant from year to year, but varied in the same way as the spots of the sun; the period being nearly 10·32 years, roughly known as the 11 year period of the sun.

The close connection between sunspot activity and the occurrence of aurora led Birkeland to the view that auroral phenomena were probably due to injection of streams of electrons coming straight from the sun in a narrow jet into the atmosphere of the earth, a view which he further confirmed by laboratory experiments repeated in recent years by Brüche. The streams, on their entry into the earth's atmosphere, are deflected by the magnetic action of the earth's field and are focussed round about the magnetic pole. The complete mathematical theory of the orbits of electrons in the earth's atmosphere has been worked out by Störmer, in several important treatises. Paulsen, on the other hand, thought that the swarm of electrons, which produces the aurora, does not come direct from the sun, but is produced by ultra-violet rays of the sun acting photochemically on the constituents in the upper atmosphere. This theory has been worked out in great detail in recent years by Maris and Hulburt and supported by numerous cogent arguments. The great difficulty of Störmer's explanation is that according to his theory, the region of maximum occurrence of aurora would be a region about 2 to 3° round about the magnetic pole, while actually the zone of maximum occurrence forms a girdle of about 20° radius about the magnetic pole. Further, as Hulburt noted, the electron-projection theories are mostly geometrical and do not attempt to go into the physics of the problem. For this, we must turn to an examination of the spectrum of the aurora which has been carried out for a long time by Vegard, Störmer and others. The most important line is a green line, the origin of which was unknown for a long time. As it apparently occurs at a great height of the atmosphere, at first sight it appeared that it must be due to a gas which is very light, even lighter than hydrogen. This hypothesis was rendered necessary because hydrodynamical calculations showed that with reasonable assumptions about the temperature distribution in the upper layers of the atmosphere, there would be very little of the heavier gases left at heights of about 200-300 kms in the regions where the aurora appear. In fact, there would be scarcely a single molecule of nitrogen or oxygen in a cubic centimetre. The upper atmosphere would consist entirely of light elements like hydrogen and helium. But surprisingly enough, neither the green line nor any other auroral lines could be ascribed to either hydrogen or helium; hence we must exclude the possibility of the existence of these elements in the upper regions. This green line was therefore ascribed to a hypothetical element even lighter than hydrogen, called Geocoronium by Wegener. But when Moseley definitely proved that there was no place for such an element in the Periodic Table, it was found necessary to look for the origin of the lines from amongst the known elements. After an epic struggle, the line was traced, chiefly due to the efforts of the late Sir John MacLennan, to the old familiar oxygen atom, in a peculiar state of excitation. The reason why this identification was not made earlier is that the line does not occur in the ordinary discharge spectrum of oxygen. It is given by the oxygen atom when it is in a metastable condition, by what is known as the forbidden transition from one metastable level to another. Though the subtility of the origin of the line, and its implication, can only be realized by one having an intimate knowledge of spectroscopy, the discovery shows that oxygen, contrary to hydrodynamical conceptions, is present in the auroral regions (80 km-400 km) in the atomic state and in a peculiar state of excitation; a closer examination of which alone can lead us to a knowledge of the peculiar physical conditions prevailing in this region.

Further examination of the spectrum of the aurora reveals lines which have been identified with those of ionized nitrogen and neutral nitrogen molecules. Recently Kaplan has reported a forbidden line of atomic nitrogen. Before we turn to an examination of the solar control of the aurora, let us consider another associated phenomena.

Night Sky Phenomena: Quiet Sun

But it is not merely the region round the magnetic poles which shows such unexpected behaviour. It has been well known that if one observes the sky from the countryside far away from the city lights at the dead of night, the starless parts of the sky do not appear to be absolutely dark, as one finds when one is placed in an absolutely light-tight chamber, but appear to possess considerable luminosity. This must originate from the upper regions of the atmosphere, even at stations far removed from the magnetic poles; hence the luminosity must be due to some other cause besides artificial stimulation by electrons which give rise to aurora. An examination of the spectrum of the luminous night sky carried out at different regions of the world reveals very interesting information. It shows the same green line of oxygen and certain other band lines which have been identified with those of nitrogen. There is, however, one important difference between the spectrum of the night sky and of the aurora. In the latter, bands due to ionized nitrogen predominate and the lines due to uncharged nitrogen molecules are very feeble. The reverse is the case with the spectrum of the luminous night sky. Here the negative bands are faint and sometimes even absent, whereas band lines due to neutral nitrogen molecules are extremely strong. The origin of the luminescent night sky must be traced to the fact that at these heights sunlight is absorbed by the atmospheric gases in the daytime and stored in some way to be re-emitted at night. A closer examination of the phenomenon therefore promises to throw much light on the nature of the solar radiation, because the night sky phenomenon can be due to no other cause except the action of the ultra-violet rays of the sun below λ 2000 Å on the constituents of the upper atmosphere.

From the above short account, it will be clear that the luminescent night sky, and the aurora, both represent optical excitation of the constituents of the upper atmosphere, but under different conditions. The former is a purely photochemical excitation, by a normal sun—the latter is due to an active sun, and further complicated by the peculiar way in which optical excitation is provided through electrons which, according to one view, come directly from the sun, but according to another, are photoelectrically liberated in the outer regions of the sunlit part, and are deflected by the field of the earth towards the magnetic poles. It will be seen that all upper atmospheric phenomena, electrical as well as magnetic, can be divided into these two main categories, as shown in the following table:

Terrestrial magnetism and its variation

The solar control of the magnetic field of the Earth is illustrated by disturbances of two types—an erratic one called Magnetic Storms, first observed by Celsius in Sweden as early as 1741, who found that the coming of the aurora was heralded by a certain amount of restlessness of the magnetic needle; the Magnetic Storms have since been much studied and have been found, in general, to occur in greater intensity and frequency simultaneously with periods of solar activity indicated by sunspots and aurora But though correspondence between the two sets of phenomena has been established in a general way, individual correspondence has not been established, i.e., every big spot has not been found to be associated with large scale auroral displays or with large Magnetic Storms.

The second type of disturbance of the magnetic needle is of a more regular nature and shows a diurnal and a monthly period. At sunrise, the NSP of the needle is slightly east of its position; at noon, it points approximately to its mean position, towards sunset it moves to the west, and regains the mean position again at midnight.

A Gaussian analysis of these types of dis-

Table

Sun	Quiet	Active	Erratic	Long Period Variations
	Eleven-year Period			
..	.	Spots, Faculae, Prominences	Bright Eruptions	80,000 years
Total Radiation	1·92 cal/per cm^2/ sec	1·92+·0007 (sunspot no.)	..	.
Optical ..	Luminous Night-sky	Aurora	.	..
Magnetic ..	Solar and Lunar Terms in Variation of Terrestrial Magnetic Elements	Magnetic storms	Magnetic pulses	..
Radio ..	E_1—region, F_1—region (day), F_2—region	General strengthening of ionization, C, D and other occasional layer formations	Radio fade-outs (short and medium waves) strengthening of long wave and atmospheric reception	..
Electrical, Lower Atmosphere	..	..	.	..
Climatic ..	?	?	?	Glacial and Interglacial epochs

turbances showed that they originate in the Earth's atmosphere and the first explanation was given by Balfour Stewart about 1860, and considerably extended by Schuster. The theory conceives that the daily disturbances are caused by horizontal movements of electric currents in the upper atmosphere across the vertical component of the Earth's magnetic field. The nature of these currents could not be explained at the time, but after the discovery of the electron, they were naturally ascribed to movements of electrons, and detailed theories of daily variation of magnetic elements were worked out by Chapman and others.

The Ionosphere

The idea that there are charged particles moving in the upper atmosphere was rescued from the cold storage into which it had fallen in a rather romantic way, when Marconi in 1898 succeeded in transmitting electromagnetic waves from England to America. When the result was communicated to the Royal Society, Lord Raleigh very pertinently remarked that the waves could not have travelled in a straight line, as there are hundreds of kilometers of solid obstacle presented by the curvature of the earth when the two stations are connected by a straight line. They must therefore be guided along the surface of the earth, or got reflected from the upper atmosphere. To explain this difficulty, Kennelly and Heaviside almost simultaneously about three years later proposed that the upper atmosphere contains a number of free electrons which form a sort of metallic shield about the earth, reflecting the wireless waves and thus keeping them confined within a narrow shell about the earth

The prediction was at that time in the nature of speculation but success of wireless propagation and the fact that all other alternative explanations were found either useless or insufficient showed that the hypothesis of the existence of the ionized layers higher up in the sky was one in the right direction. Precise theory has evolved as a result of successful refinements by Eccles, Larmor, Appleton and others. At the present time it is known that the electrons which act as reflectors of the wireless waves are stratified in different layers of which two are permanent They are known as the E_1 which is at a height of about 100 km, and F_2 discovered by Appleton in 1923, which is at a height of about 200-250 km. Methods have now been perfected for finding out the night and day variation of the heights of these layers, their maximum electron concentration and variation of these quantities during the hours of day and night and also during the whole year. In addition to these permanent layers there are subsidiary ones, of which mention will be made later.

Source of free electrons: Photo-ionization

We can now ask ourselves about the origin of these electron layers. Here, as in the questions about the origin of the aurora, there were long controversies whether these layers were formed by electrons coming direct from the sun as originally proposed by Birkeland, or were they due to electrons liberated by the ionizing action of ultra-violet sunlight. The question was answered in a decisive way by observations of the density of electrons during the total solar eclipse of 1932. These showed conclusively that at least in the E and F_1-regions the electrons were produced by the ultra-violet sunlight because, during the instant of totality as soon as the light was cut off, the density of electrons fell to a very small value. It is therefore clear that the production of electrons in the E and F_1-regions is entirely controlled by the sun, through its ultraviolet radiation.

A thermo-dynamical theory of ionization of the upper air constituents by the ultra-violet rays of the sun was worked out in a general way six years before the eclipse observations gave a clear reply to the controversy by Prof Pannekoek of Amsterdam in 1926. In 1931 Prof Chapman, following an earlier work by Lenard, worked out a *mathematical* theory of the production of electrons by monochromatic light which enabled one to obtain a formula showing the variation of electron concentration with the zenith angle of the sun. We have here the gases constituting the earth's atmosphere, which are being traversed by the rays of the sun at varying angles. The rays produce the dissociation of molecules into atoms, and ions and electrons. But these processes cannot go on unchecked, and the free ions and electrons recombine producing again neutral particles and sometimes the electrons attach themselves to elements having electron affinity and form negative ions.

The general theory of ionization of the atmospheric constituents by sunlight was worked out by Pannekoek by extending the theory of Thermal Ionization given by the present author six years earlier with the aid of a modification proposed by E A Milne for the case when the temperature of radiation is very different from that of the gas traversed. Pannekoek calculated the equilibrium number of electrons produced by the sunlight from nitrogen, oxygen and hydrogen molecules making certain plausible assumptions regarding the quantities which are needed for the calculation. These are the ionization potentials of the molecules and the elements, the temperature of the sun regarded as a black body, and the temperature of the upper atmosphere. The values adopted for all these quantities were rather rough, but nothing better could be done at that time. Pannekoek was, however, able to show that the number of electrons obtained from such calculations and the height at which the maximum concentration occurs were in rough agreement with the number obtained from the ionospheric experiments. By 1931 much more was known about the ionosphere, e.g., there was, thanks to the work of Appleton, Nichols and Schelleng, Gilliland and Kirby, precise information regarding variation of the maximum number of electrons in the E and F-layers, during hours of the day, with season and latitude, and to account for these Chapman worked out in greater detail the variation of the number of electrons produced by a monochromatic beam of light when the rays of the sun fall at different slanting angles and was able to show that his conclusions were in substantial agreement with the results just mentioned. Chapman's theory is, however, severely mathematical and he had to assume that the equilibrium is of the unicomponent type, that is to say, the electrons are produced from one component, say from the nitrogen or the oxygen molecule or the oxygen atom, and the electron produced combines with the ion of that component alone. But on account of mathematical difficulties the theory, although in a position to explain the results of observations for the E and F-regions roughly, did not enable him to make any calculation of the actual number of electrons produced as Pannekoek had done. In fact, the two theories existed side by side, and no connection was shown between them.

This fact and the arbitrary assumptions regarding the values of the ionization potentials, and of the values of the absorption coefficients of the photo-ionizing radiation made it extremely desirable that the foundations of both the theories should be further critically examined.

A beginning in this direction has been made by the author and R N Rai. It is a re-working of the Pannekoek theory, since they found that the Chapman theory was implicitly contained in the fuller theory of Pannekoek. But they have shown that a satisfactory theory involves accurate knowledge of many factors, such as absorption coefficient, ionization potential, etc. Some of these, e.g. ionization potentials which were roughly known when Pannekoek gave his theory, had been more precisely determined by 1936. But a knowledge of IP alone is not sufficient, as information must be available regarding the intensity and variation of the absorption coefficient of these radiations with frequency for atmospheric constituents, atoms or the molecules concerned. The necessity of this was not realized before, but as the height of maximum ion-production varies inversely as τ_0, the maximum absorption coefficient, the importance of determining accurately the nature of $\tau(v)-v$ curves becomes apparent.

The previous workers had used for this purpose a formula given by Kramers, which was deduced on the basis of the old quantum theory for explaining the absorption of X-rays by matter. But, as Rosseland remarked, the usefulness of the formula was over-stressed, and even in the case of hydrogen, where it is most expected to hold, Leigh Page has recently found the formula defective. The best course would have been to obtain the nature of $\tau(v)-v$ curves from actual laboratory experiments, but obviously such experiments can be carried out only for O_2 and N_2, and it cannot yet be seen how they can be carried out for O and N-atoms. Even in the case of molecules, the experiments are very difficult, and complicated by other phenomena. But such experiments as exist (e.g., those of Hopfield and Takamine) and their theoretical interpretations show that for each of the O_1 and N_2-molecule, two types of ionization exist—first, a feeble one, caused by a forbidden electronic transition, and the second one, caused by an allowed transition. The τ-values for the two processes are entirely of a different order, the second process being at least 10^4-times more intense than the first.

A tentative wave-mechanical theory for photo-ionization of atoms like O and N can be worked with some effort, but it appears wrong to utilize the same or a slightly modified formula for molecular photo-ionization. It is rather surprising that no theory of photo-ionization of molecules has yet been attempted. A beginning in this direction has been made by B D Nagchowduri and K M Bose for H_2, but the cases of O_2 and N_2 present almost insuperable mathematical difficulties In this connection it may be noted that the $\tau(v)-v$ curve does not begin with a maximum at τ_0, the minimum photo-ionizing frequency, but is reached at some distance, depending on the values of the nuclear distances of the atom, and the ion respectively. Further, the curve is not smooth like that of the atomic photo-ionization curve, but is broken up at points $v=v_0+n\omega$, where ω is the frequency of vibration of the ion, and n is the number denoting the upper harmonic.

It will possibly take some time before such curves, so much necessary for calculating ionization of the upper atmosphere, are accurately determined. It is, however, pleasant to notice that Takamine has already started such experiments, and obtained a certain amount of verification for ionization of the N_2-molecule by neon-light.

Formation of Electron Layers

An unexpected result, which comes from the revised Pannekoek theory of ionization, is a successful explanation of electron layer formation, which was originally attempted by Lenard and more fully from the mathematical point of view by Chapman. They showed that if *monochromatic light* is absorbed by atmospheric constituents with liberation of electrons, the constituents being assumed to be distributed according to isothermal equilibrium, a layer of electrons is formed in the regions where absorption takes place. The electrondensity attains a maximum at a certain level, where the pressure is proportional to Mg/τ_0, and falls off nearly parabolically on both sides. The half width of the layer varies as $\frac{kT}{Mg}=H$, usually known as the height of homogeneous atmosphere. This theory was roughly verified by investigations of the form of the lower side of the E_1-layer and the F_1-layer It appeared that to explain the form of the E_1-layer, it has to be assumed that H is small, of the order of 10-15 kms., while that of the F_1-layer is about four times as great. These might be ascribed to the fact that the temperature of the F_1-region is, according to some workers, about four times larger than that of the E-region, but if the F_1-region is due to ionization of the oxygen atom, as suggested here, we need not make the temperature four times larger than that of the E-layer. A temperature double that of E would do.

But apart from other difficulties Chapman's work was insufficient in one respect, namely, that it was proved only for monochromatic light, whereas actually if we suppose the sun to be a black body at 6000°K the ionizing radiation should consist of the whole spectrum beginning from a certain limit and extending indefinitely towards the ultra-violet. It could not be seen off hand if ionization by such a spectrum would not destroy much of the properties of the layer. But in the revised theory, it so happens, and it is a rather unexpected result, that even continuous spectrum produces a layer very much similar to the simple one made familiar by the work of Chapman. It must be admitted, however, that the form of the layer depends to some extent on that of the photoionizing absorption curve, which is not yet known for the ionization processes actually occurring in the atmosphere but is only deduced from a plausible theory. As long as this is not known, it is of course not possible to give further precision to the theory, but approximate values of electron concentration can be obtained with the aid of some plausible assumptions regarding the radiation from the sun and the temperature of the Upper Regions.

These considerations, therefore, lead us to the conclusion that the different stable layers as observed in the ionosphere are due to ionization, by the appropriate solar radiation, of distinct constituents of the atmosphere, viz. N_2, O_2, N, O, the maximum of the layer occurring at the height where total absorption of ionizing radiation by the particles reaches its maximum value. We may proceed to identify the processes. The E_1-layer must be due to a process of ionization which is effective only at a height of 100 kms. As the amount of gaseous oxygen and nitrogen molecule above this height is of the order of a few cms, the radiation which causes E-layer ionization should be such that it can be transmitted through a few cms of nitrogen and oxygen gas at NTP. These considerations prove that the E-layer is probably formed by the first process of ionization of O_2 and N_2 at 12·2 and 15·5 volts. The pressure at the apex of the layer is given by $P \simeq \frac{Mg}{\tau}$. Now for an allowed transition, τ_0 is of the order of 3×10^{-17}; for a forbidden transition it may be taken to be 10^4-times smaller, say 10^{-22}. We then get $P = 10^{-2} - 10^{-3}$ mm. of mercury. This is just the pressure in the E-layer. The F_2-layer, on the other hand, should be due to ionization by radiation which can be stopped by about a thousandth mm. of the gas, because at a height of 200-250 km, where this layer is formed, the amount of gas lying above cannot exceed this amount. We can easily link up this fact with the second ionization of N_2 and O_2 which gives rise to excited O_2^+ and N_2, because the ionization occurs with an intensity which as mentioned before is about 10,000 times stronger than the first ionization. The pressure, calculated from the formula $P \simeq \frac{Mg}{\tau}$ is of the order of 10^{-6} to 10^{-7} mm which is of the order of pressure at the F-layer. The F_1-layer is a purely daylight phenomenon. It is found that the night F-layer splits up into F_1 and F_2 when the sun is sufficiently high up in the sky and towards nightfall, when the sun's altitude has fallen, F_1 and F_2 unite to form one single layer. The F_1-layer is therefore a purely daylight phenomenon and is probably due to an extra process besides ionization which is operative only during daytime. All the available knowledge supports the view and this has also been mathematically demonstrated by Dr R C Majumdar that during daytime the oxygen molecule probably completely dissociates into atoms at a height of about 200 kms on account of absorption of radiation between the wavelengths 1750 Å and 1300 Å, a process which has been very thoroughly studied in the laboratory by Ladenburg and Van Voorhis. P, the pressure at which the maximum absorption of this radiation occurs, is of the order of 10^{-4} to 10^{-5} mm of mercury and hence it is between the E- and F-layers. The electrons which give rise to the F_1-layer must be due to further ionization of the oxygen atoms, so produced during daytime. At night time or when the sun is sufficiently slanting, probably most of the oxygen atoms at this level would recombine to form molecules and therefore the F_1-layer will disappear, as there are not sufficient oxygen atoms to be ionized.

The F_2-layer

This explanation may appear to be apparently at variance with certain other observations, for example, the anomalous behaviour of the F_2-layer. It has been already remarked that the formation of the E_1- and F_1-layers follows solar control and it demonstrates approximately the validity of the theory of photo-ionization by sunlight and theory of recombination as in a unicomponent system. The concentration in these layers attains a maximum at about noon and follows the fourth power of the cosine of the sun's zenith angle, a result which can be deduced from these theories. The seasonal variation is also in accordance with the theory of solar control. But not so with the F_2-layer for which maximum concentration is found to occur for Slough in summer at about 9-10 AM, is followed by a minimum at 2 PM, followed by a maximum at 8 PM, and a pronounced minimum at 3 AM. Even during winter, though a midday maximum is obtained, there is an unaccountable smaller maximum at midnight. For other latitudes as well, the behaviour is anomalous. During total solar eclipses, the F_2-region ionization appears to remain unaffected All these and other facts show that either the solar control theory is insufficient for this region, or in working out the theory of photo-ionization we should not regard the system to be a unicomponent one. Probably in the F_2-region the pressure is so low that collision between the electrons and ions must be extremely infrequent, and neutralization takes place after intervals of the same order of magnitude as the day; hence the equilibrium theory has probably to be considerably modified.

It must not be supposed that even if we except the highly perplexing features of the F_2-region, the theory of solar control can explain all the characteristics of the ionosphere. Rather puzzling is the persistence of ionization in the E-region at night. According to the solar control theory, the E-region should entirely disappear as soon as light is withdrawn because in this region collision frequency is quite large (10^5 in a sec) and recombination must be very quick, but we find that there is residual ionization, about 1/20th of the maximum amount, which is present throughout night. It does not appear probable that this is due to positive ions. We must therefore suppose, as Martyn and Pulley have done, that at night there is probably some mechanism at work by which fresh electrons are produced. It is not improbable that a neutral molecule colliding with a negative ion might knock out the electron, and supply the electrons necessary for maintaining the residual E-layer at night.

A complete theory of the various puzzling ionospheric phenomena will probably take years of work. Much depends on the correct interpretation of the results obtained by the method of reflection of radio waves from the ionosphere. It must not be supposed that the magneto-ionic theory of propagation of e.m. waves which is now holding the field is infallible.

Radio Fade-outs

Probably the solar control of the upper atmosphere is nowhere more strongly illustrated than in the phenomenon of Radio Fade-outs, which has been studied in recent years as an international programme by a number of workers in Europe and America, particularly by Dellinger in the USA and Jouast in France. It was observed for some years that sometimes radio signals which were being usually received from a distant station suddenly stop and the normal conditions are obtained after a lapse of time which extends usually over a few minutes. Observations showed that many of these sudden radio fade-outs were simultaneous with the appearance on the surface of the sun of small bright patches of intense white light observed by Carrington as early as 1859. Spectroscopic observations carried out at Mt. Wilson and elsewhere showed that these patches emit the Balmer lines of hydrogen in great strength. From the international programme carried out by Dellinger and Jouast it was found that the phenomenon is confined only over the sunlit part of the globe and the interruptions were simultaneous over different parts of the earth within the sunlit regions, and that the sudden stoppage was connected with intense chromospheric eruptions, though all eruptions did not give rise to radio fade-outs. Further investigations showed that neither the ionization nor the height of the E- and F-layers was very much disturbed during these sudden radio fade-outs. The cause of the disturbance must, therefore, be sought below the E-region or in an intense transitory ionization of the regions below E, which is sometimes called D by Appleton. This is further confirmed by an increase in intensity of long-distance radio by means of very long waves during radio fade-outs, which refer only to short and medium waves, because long waves are reflected from the low, i.e., D-layer. Further, the radio fade-outs are accompanied by magnetic disturbances of short duration, which are strongest over the part of the globe directly under the sun at the time of the eruption. This shows that the small patches send out flares of ultra-violet light which produce intense ionization of the region D.

Let us see how this flare works. The great strengthening of the hydrogen lines is merely a token that something unusual is happening on the sun. Spectroscopy tells us that when the Balmer lines are emitted in great strength, the Lyman lines would in fact be far stronger, but it can be shown that neither the Balmer lines nor the first two Lyman lines can produce any ionization in the atmosphere, because the amount of energy they carry is below the critical limit required for ionizing any of the atmospheric constituents. It is only the third Lyman *y* and the subsequent lines which can ionize O_2 to O_2^+ by the first process of ionization which, being feeble, can penetrate to lower levels. This is also confirmed by the experiment of Takamine and Suga who found that the L_y and L_p lines can be transmitted in undiminished strength through thin columns of O_2, but the slightest trace of O_2 obliterates L_r. There may be, besides, radiation of other elements of approximately the same wavelength and they will reach the D-level which contains, above itself, nearly 11 cm of N_2 and 0·57 cm of O_2 at NTP. The above is only a suggestion. The particular part of the solar spectrum which is responsible for the extra ionization in the D-layer will be only found out after extensive research But the phenomenon illustrates that even transient disturbances on the surface of the sun find their echo on the doings of mankind on the earth, which involve the upper atmosphere.

Tentative theories of the Luminous Night Sky

We might briefly pass over the problem of the luminous night sky phenomenon, which has been briefly reviewed earlier. There is no difficulty in comprehending that the luminescence of the night sky must be in some way intimately connected with the action of sunlight on the constituents of the Upper Atmosphere. But the great puzzle is the persistence of the phenomenon. Take for example the green line, which is a permanent feature of the night sky. We can suppose that during daytime, photo-electric action of the solar rays decomposes oxygen molecules into normal O atoms and excited O atoms, and the excited ones if they are in the $O‘S_0$ -state revert back to a lower state giving rise to the green line. It must be added, however, that no such photo-electric phenomenon has yet been discovered. This explanation cannot hold for the night sky emission of the green line, because the life of no excited atom can ever be much larger than a second, and hence as soon as sunlight is withdrawn all metastable oxygen atoms will promptly revert back to the normal state. How does the green line then originate in the night sky? The only explanation which promises a certain amount of success is a theory of recombination between ions and electrons, which must be going on when sunlight is withdrawn from these heights. At daytime in the F-region, illuminated by sunlight the upper atmosphere would consist mainly of electrons and ionized atoms of O and N and probably also of O_2^+ and N_2^+. When sunlight is withdrawn at night, the electrons will combine with the ionized atoms and molecules. To fix our attention, let us take the case of O+. An electron colliding with it may form oxygen atom in the normal state as well as any one of the two metastable states (O'S or $O'D_2$). The metastable states, after they are formed, will emit the green line or the red line and revert back to the normal state after fraction of a second, because they have nothing else to do. This theory of night sky luminescence recalls to the mind of the author the stimulating theory of Zanstra of emission lines of Planetary Nebulæ, all of which are forbidden lines of the type of the green line. This also explains to some extent the Height-effect of Vegard, who found that the green line is intensified in the higher part of the sky. The explanation is that at the lower parts, the $O'S_0$-atom will collide with other particles and lose its energy by collisions of the second type before it has a chance to radiate. The emission of the green line is therefore a consequence of recapture of electrons by the O^+-ion, and its persistence is due to infrequency of collisions in this region due to small pressure. It is estimated that at these heights, the mean free path of the electron is extremely large, say about 10^8 cms., and the velocity is probably in the neighbourhood of 10^7. So there may not be more than one collision per second but only one in 10^5 gets captured to form an $O'S_0$, or $O'D_2$-atom. These will then have nothing to do except radiate the green or the red auroral lines. We can by the same hypothesis explain the absence of the negative bands of nitrogen from the night sky spectrum. It is well known that the negative bands arise from an excited state of N_2^+ which however can be produced by direct ionization of normal N_2 by ultra-violet sunlight possessing an energy of the order of about 21 volts. Any excited N_2^+ which is produced in these upper layers must immediately disappear as soon as sunlight is withdrawn, a hypothesis which explains in a convincing way Slipher's observation that during the morning or evening flash of sunlight, the negative bands of nitrogen are obtained from the upper atmosphere in great strength but they disappear as soon as sunlight passes away. At night time therefore the N_2 -ion which remains in non-luminous and there can be no further emission of negative bands. unless N_2^+-normal is further activated by electron impact. The electrons will combine with this N_2^+ forming different excited states and immediately after the recombination, the excited N_2 will revert back to the lower states giving rise to the second and first positive bands and the Vegard-Kaplan bands. The persistence of luminosity in the sky throughout the night, therefore, seems to be due to the fact that on account of extreme rarefaction at these heights, the rate of recombination is extremely slow. As a matter of fact even without fresh sunlight, the electrons and free positive ions can probably exist for days together, as is shown by the existence of the F_2-region in the polar atmosphere, even when these regions are perpetually in the dark for days together.

Astrophysical Theories of the Sun From the above incomplete review it will be clear that a correct interpretation of the upper atmospheric phenomena suffers greatly from the desiderata that we have no direct knowledge of the ultra-violet part of the solar spectrum as it would appear to an observer outside our own atmosphere. For our purpose, this knowledge is most important because almost all the Upper Air Phenomena are due to the action of ultra-violet light on the constituents of the atmosphere and when a disturbance takes place on the sun, it is the ultra-violet radiation which is most affected. But the question may be asked why not tackle the question from the astrophysical side? As a matter of fact, astrophysicists have not been idle. Mention may be made of a famous paper by Sir A S Eddington which aimed at giving a quantitative idea of the formation of Fraunhofer lines and its subsequent extensions by Milne, Chandrasekhar, Wooley and Stromgren. But if one goes very deeply into the fundamental assumption underlying these works, it is found very difficult to be able to agree with many of their basic assumptions, e.g., there is no reason to suppose that the radiation from all layers of the sun should be black body radiation. In fact, the assumption is positively contradicted by certain observations. If the temperature of the surface of the sun, which gives us the continuous background of light, were 6000°K, it can give us only such absorption lines which require moderate excitation and the chromospheric spectrum would give us emission lines whose excitation potential should not be greater than 6 to 9 volts. But it is a well known fact that the chromospheric spectrum of the sun gives us the lines of helium requiring an excitation potential of over 20 volts and also a line of helium$^+$ ($\lambda = 4686$ Å) which requires an excitation potential of about 79 volts. It is therefore clear that the common notion that the sun radiates like a black body at a temperature of 6000°K can only be an approximation and a very rough approximation indeed. In fact, the Russian observers, Perepelkin and Melnikov, in a publication from the Pulkovo Observatory have shown that the intensity of these emission helium lines is almost nil on the limb of the sun, and gradually rises to a maximum at a height of 2500 km. in the solar atmosphere and then steadily falls. This shows that the mechanism, which is responsible for the emission of these helium lines must be very different from what is associated with a state of black body radiation. We can suppose that the intense ultra-violet radiation from the interior passes through the upper layers of solar gases, produces ionization in these layers and subsequently these ionized electrons and atoms recombine giving rise to the intense helium lines which are observed from the chromospheric spectrum of the sun but are absent from the Fraunhofer spectrum. If the lines of subordinate series to which belong most of the helium lines in the visible and the He$^+$-line λ 4686Å can come out prominently, it is clear from fundamental consideration of atomic excitation that the line of the fundamental series λ 584 Å due to He, and λ 304Å due to He$^+$ should come out still more prominently. Thus if we could observe the spectrum of the sun in the ultra-violet region, probably the principal lines of helium, hydrogen and iron$^+$ and many other elements would be obtained as emission lines. But at the present time all theoretical works would be merely speculative. The decisive evidence would be obtained if a spectrum of the sun could be secured at a height of 40-50 km. i.e., considerably above the ozone layer.

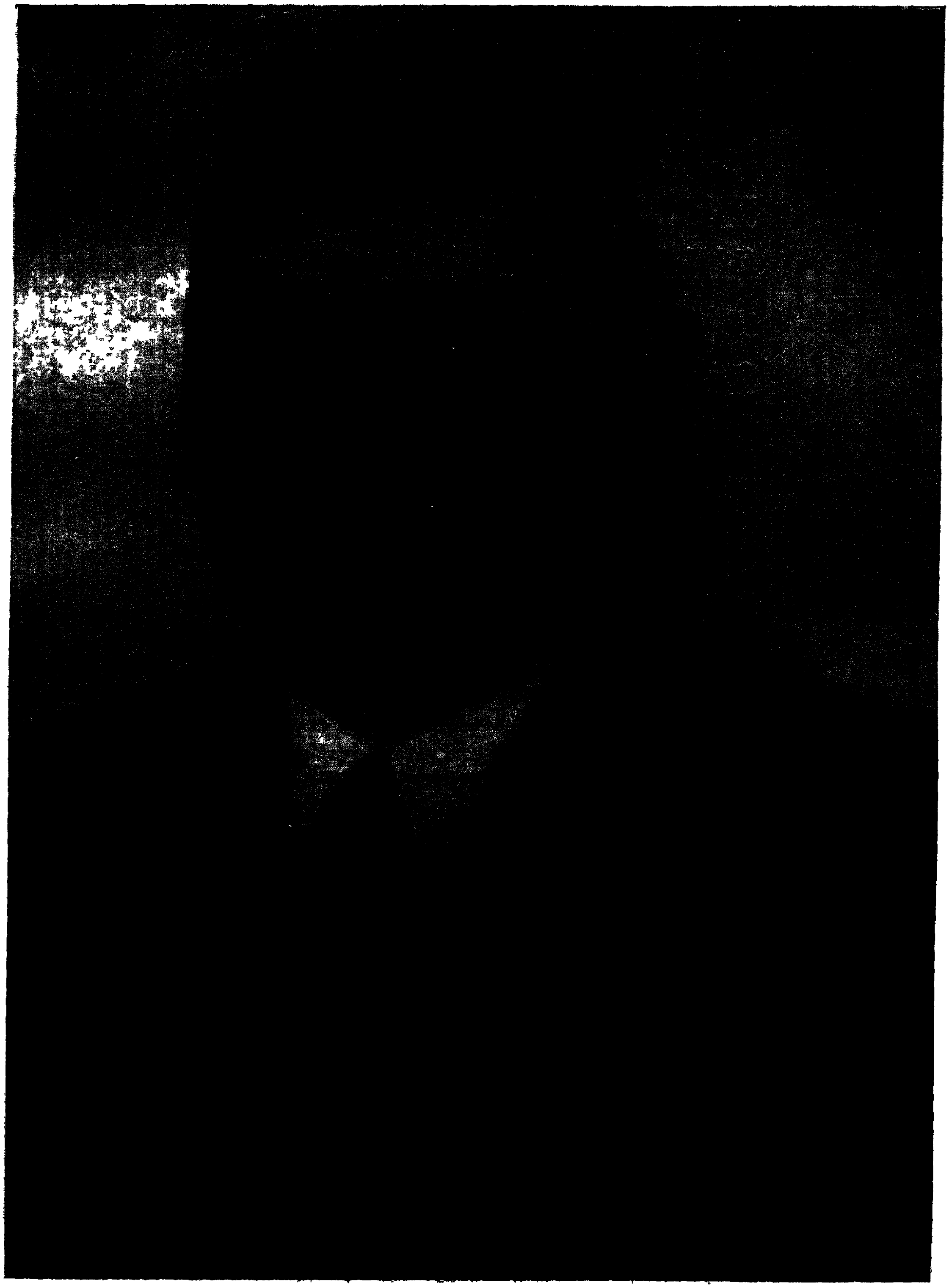
The above short review shows that though it is easy to postulate that the atmosphere, upper as well as the lower, is entirely controlled by the sun, it is very difficult to work out the details and present a complete unified theory. For this purpose we must know more about the normal behaviour of the sun, as well as of its abnormal behaviour which is manifested in the form of sun-spots, prominences, faculæ, the small patches of intense light responsible for radio fade-outs. But even this does not appear to be the whole story.

Long Period Variation of the Sun

In a very thought-provoking paper Sir George Simpson has pointed out that in addition to the short period variation, the sun has also probably a long and somewhat irregular period of variation, extending to about over 80,000 years. He supposes that there is a periodic fluctuation in the amount of radiation which is emitted by the sun. When the amount increased, it caused on the earth intense cloud formation in the equatorial regions, and this, paradoxically enough, caused intense glaciation over the poles. In this way he has been able to explain successfully the occurrence in the Pleistocene age of four successive glacial epochs separated by interglacial ones observed in Europe by Penck and Brückner and connected by the anthropologists with the different cultural epochs of *Homo sapiens*. Possibly the Chellean epoch, when *Homo sapiens* began to make tools and thus lay the foundation of civilization, was started by such a caprice on the part of the sun. It is a thought-provoking idea, but the astronomer has probably no chance of verifying it, as neither he, nor the civilization of which he is a bye-product, can hope to exist for 80,000 years. This short review will, I hope, convince you that the romance of our knowledge of the sun is still in the making.

Brevet Colonel Sir Ram Nath Chopra, FNA*

(Foundation Fellow; President, 1939-40)



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Professor R N Chopra was born in 1882 in a respectable Dogra family of J & K State. He received his LRCP, MRCS (Eng) in 1907 and MB, BCh (Cantab) in 1908 and MD in 1912. He was the Professor of Pharmacology (retired as Director in 1941) at the School of Tropical Medicine and concurrently Professor of Pharmacology at Calcutta Medical College; Chairman, Drug Enquiry Committee (which recommended All India legislation for a 'Drug Act' and a 'Pharmacy Act'); Director of Medical Services and Drug Research in J & K State (1941-61). Professor Chopra was awarded MRCP and FRCP from the University and College of Physicians and Surgeons of London. The Pharmaceutical Society of Great Britain admitted him as an Honorary MPS. He served in the Export Panel on Drug Addiction of the WHO. He was the Honorary Member, American Society for Pharmacology and Experimental Therapeutics, Inc. As a distinguished member of Indian Medical Service, he was raised to the rank of Brevet Colonel much before his turn. He was knighted with a KIH (Gold Medal). He was General President, Indian Science Congress (1948), Life Member and Fellow (Vice-President 1938-40) of the Asiatic Society.

Professor Chopra was the pioneer in building up Indian Pharmacology. He carried out research in various aspects of Tropical Medicine, Experimental Pharmacology and Therapeutics, Drug Addiction, Indigenous drugs, Drug Standardization, Toxicology, Clinical Medicine, Newer Laboratory Techniques and Methodology in diagnostic work etc. He laid emphasis on Indian indigenous drugs—their chemical composition, the physiological action of their active principles on living tissues *in vitro* and *in vivo*, and the biochemical and biophysical changes brought about in mammalian organisms on the administration of these active principles.

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*died in 1978.

ORGANISATION AND DEVELOPMENT OF SCIENTIFIC RESEARCH IN INDIA WITH SPECIAL REFERENCE TO MEDICINAL FLORA

R N Chopra

(delivered at Madras, 1940)

Resources of India: India has fortunately been richly endowed by nature with all that any country can possibly need. While primarily an agricultural country, with extensive agricultural and forest lands capable of yielding almost all kinds of foodstuffs, timber and other economic products, it also has very rich resources of various minerals on which depends the highly industrialized life of the present times. Its power resources in the way of coal and water power are also very extensive, but have not been adequately developed. According to Sir M Visvesvarayya only 2% of the Hydroelectric resources of India have so far been developed. In those respects India can rightly be designated as one of a triumvirate with the United States of America and the Russian Socialist Federated Soviet Republic, the only two other countries of the world which have almost unlimited agricultural, mineral and power resources. As compared to the other two units of this triumvirate, however, these resources in India have for want of a systematic policy of industrialization not been developed, and naturally, therefore, India stands very low in the list of industrialized countries of the present day. This unfortunate position of India is intimately connected with the organization and development of scientific and technical education and research in the country and the lack of an industrial policy. A very serious situation has suddenly arisen as a result of the war which Germany has forced on the world and the repercussions of which are already materially influencing life in every country. Its direct effects on India are already becoming a source of great concern both for the authorities and the public at large, as we are dependent for the great majority of manufactured commodities on imports from foreign countries. This has been brought home to me very forcibly in connection with the drug industry, which seemed to be apparently making a headway, but the outbreak of war has brought to the fore the very serious problem of the supply of the basic materials for the manufacture of medicinal preparations practically all of which were being imported from foreign countries. This is a situation which no self-respectiog country should face with equanimity. It would not, therefore, be out of place if I may briefly review the situation to-day and indicate the urgent necessity for the proper planning and organization of scientific research as this alone will make it possible for India to assume its proper place in the comity of nations, and be as independent as possible of imports from other countries of even the daily necessities of life.

Progress of scientific education and research: Sir Lewis Fermor and Dr Baini Prashad have within recent years discussed the organization and progress of scientific education and research in India, and the late Lord Rutherford also included a brief review in his Presidential Address to the joint session of the British Association for the Advancement of Science and the Indian Science Congress Association in 1938. It would, therefore, suffice if I include only a very brief summary here.

Education on Western lines was introduced into India within comparatively recent times and it is, therefore, remarkable that its progress in the country has been so rapid. The first universities in this country were founded at Calcutta, Bombay and Madras in 1857, but these and others founded in the latter half of the 19th century were only universities of an affiliating type and their energies were mainly directed towards examining students for various examinations and degrees, rather than serving as centres of teaching or research. With the passing of the University Act of 1904, however, most of the universities instituted courses for advanced studies and special Honours courses in scientific subjects and, by the appointment of professors and lecturers and the extension of libraries and laboratories, materially advanced the cause of scientific teaching and original research in the country. A start had been made in regard to scientific education in the latter half of the 19th century, but this teaching was mainly confined to preliminary studies rather than more advanced teaching or research. The major part of advances to our knowledge in the scientific sphere in India up to the beginning of the 20th century was due to the scientific departments of the Government and work of independent workers who devoted their spare time and energies to studies in subjects which interested them. In a number of cases such devotion to research was looked down upon, and I cannot do better than cite the classical example of Sir Ronald Ross who was actually rebuked for devoting all his spare time to the study of mosquitoes; this incidently resulted in the discovery of the very important role played by mosquitoes in the spread of Malaria.

University education since this period has progressed at a remarkably rapid rate, but the reorganization of the secondary school system to guarantee a sound basic education and primary scientific training, and the reorganization of the University studies with a view to ensuring a sound knowledge of the fundamental sciences to serve as a foundation for advanced study and research are still urgent desiderata.

Necessity for development of research activities: In the recently reorganized teaching universities in addition to their capacity for imparting training in various scientific subjects, research qualifications in the case of the professors and lecturers were rightly regarded as requisites for appointment and promotion, but Prof Saha rightly pointed out the defects of the present-day situation when he remarked that 'owing to intrigues by vested interests, and defects in the constitution, these ideals are being lost sight of, nay even abandoned in many of the universities, and some of them are being reconverted to the high school stage from which they were rescued by the reforms of 1921-22.'

After the World War of 1914-18 greater attention was paid to the reorganization, on a more extensive basis, of the various Government scientific departments and research institutions, and a number of special research institutions were founded. Unfortunately the Board of Scientific Advice, which the Government of India had established in 1902 for the co-ordination of scientific work carried out by its official agencies, was closed down in 1924, and though proposals for the foundation of a National Research Council to replace this Board have been under consideration for several years, the scheme has not hitherto materialized. The Indian Research Fund Association which was founded in 1911 for the prosecution and assistance of research in connection with the causation, mode of spread and prevention of diseases in India has been carrying on a very useful work, but for want of funds its activities have been greatly restricted since 1931. The Imperial Council of Agricultural Research constituted in 1929 and the Indian Central Cotton Committee and the Indian Central Jute Committee, have done very valuable service in arranging agricultural, technological and economic research in connection with agriculture, in effecting the improvement of various types of crops, and in studying the factors connected with the marketing of the products, but even here lack of funds has been a serious hindrance in the way of progress. Though a number of official organizations exist for the development of Medical and Agricultural Research, there are no institutions worth the name for the advancement of Industrial Research. Various private bequests resulting in the Indian Association for the Cultivation of Science, Calcutta, the Tata bequest resulting in the foundation of the Indian Institute of Science at Bangalore, Sir Tarak Nath Palit, Sir Rash Behary Ghosh and Khaira bequests leading to the establishment of the University College of Science at Calcutta, the Bose Research Institute, Calcutta, founded and endowed by Sir Jagadish Bose, Rai Bahadur Lakshminarain bequest to the University of Nagpur, the Maharaja of Jeypore bequest leading to the foundation of the Science Departments of the Andhra University, contributions from the Rockefeller Foundation towards the All-India Institute of Hygiene and Public Health and the Attock Oil Company bequests to the Punjab University are responsible for the creation of a number of important agencies for the advancement of higher teaching and research in various sciences. With all these, however, the facilities for teaching and research in various sciences in the vast sub-continent of India have been and still are very limited, and it is, therefore, a matter of real pride that in spite of these handicaps Indian students of science have, during this short period of a little over a quarter of a century, justified their capacity for original investigation. In the words of the late Lord Rutherford 'India is now taking an honourable part and an ever increasing share in the advance of knowledge in pure science'. As Prof Saha, however, very cogently pointed out, 'the time has now come not only to strengthen the scientific surveys and the research atmosphere of the universities, but we ought to enter on a third phase, namely, scientific research should now be applied for solving the industrial problems of the country'.

Value of Industrial Research: Lord Rutherford in his Presidential Address, already referred to, gave a very valuable summary of the organization of industrial research in Great Britain, and, though great differences exist between agricultural and industrial conditions in Great Britain and India, it would be of value to give here a brief summary of how the British Government have contributed to the promotion and organization of industrial and agricultural research in the period since the World War of 1914-18.

Prior to the World War progress in industry 'depended, in the main, on the brilliant contributions of individual workers, rather than on any systematic attack by scientific methods on the problems of industry'. The World War, however, brought the industrialists and the men of science into closer contact to their mutual benefit. The Government also recognized that a more systematic application of science and research over a broader field was essential in the national interest, and in 1915 a special Department of Scientific and Industrial Research was founded. This was followed by the Medical Research Council in 1920 and the Agricultural Research Council in 1931. In fact, the establishment of the Department of Scientific and Industrial Research marked the first organized measure taken in Great Britain for helping industry through the application of science. Several new organizations controlled and financed by this Department were set up to deal with the scientific aspects of the use of fuel, of the storage and transport of food, of buildings, roads, etc., and the famous National Physical and the Chemical Research Laboratories at Teddington were developed under the aegis of this Department. As a result very important national organizations have been built up for the investigation and application of science to various problems connected with the daily life of the people and the nation's industry as a whole. 'In the British organizations there is no political atmosphere, but of course the responsibility for allocating the necessary funds ultimately rests with the Government.' The planning of the programmes of research, however, 'rests with research councils or committees who are not themselves State servants but distinguished representatives of pure science and industry', this work being mainly in the hands of the Advisory Council of the Department of Scientific and Industrial Research. Similar research organizations under the control of Research Councils or corresponding bodies, which have been set up in Canada, Australia, New Zealand and South Africa, are responsible for the rapid scientific and industrial developments in these dominions.

National Research Council for India: The late Lord Rutherford in discussing the development of industrial research in Great Britain remarked:

'Even in a large country like India, where the resources and needs of the different Provinces are very varied, it seems to me essential for efficiency that the organization of research should be on national rather than on provincial lines. The setting up of separate research establishments for similar purposes in the various provinces cannot but lead to much overlapping of work and waste of effort and money. Such a central organization of research does not necessarily mean that the scientific work should all be concentrated in a single laboratory.' If research work is to be of real and lasting value it must be carried out in the interests of the country as a whole and not of any particular province or area. As was well summed up in a leader in *Nature*, 'This necessitates careful planning and co-ordination of various schemes for research in all branches of science, whether pure or applied. In formulating the future policy, India should profit by the experience of Canada and Australia where the working of the scientific departments of the State or Provincial Governments *vis-a-vis* those of the Central or Federal Government has shown that the research organizations of the country should be truly national and responsible to the Federal Government alone. The detailed planning of research must be in the hands of those with the necessary specialized knowledge, and they must be able to act without suspicion of political or racial influence.' In other words, a plea is made for the foundation of a National Research Council in India on the lines of the body which ever since its constitution has been rendering such useful service in Great Britain. The Council should not only define the policy but act as an expert advisory body for planning and co-ordinating all scientific research in the country. The planning of scientific policy and co-ordination of research should be so arranged as to preclude duplication and avoid wastage of talent and available funds, but without in any way restricting the normal work of the universities, scientific departments and institutions, or in any way curbing individual initiative which is always so essential for high class research. Such an authoritative body should also be able to help in bringing about the necessary reforms in the existing system of scientific education. The Council should be liberally endowed so as to be independent of annual appropriations for carrying out all its programme of work.

Scientific and Industrial Research: Pure scientific research is as essential as that specifically devoted to the attainment of any industrial object. While industrial research is confined specifically to investigations which have a direct bearing on the development of any industry, it would be a truism to assert that discoveries made in the domain of pure science may and often find application in industries at a later date, and that 'industrial application, though its precise form cannot always be foreseen at the time, has come to be an expected incident in the after-life of the discovery'. This principle is fully accepted in the highly organized machinery for industrial research in the United States of America, and as a result a great deal of importance is attached to researches in pure sciences. The connection of such researches with any of the industries is often not obvious, but all the same they are encouraged in the hope that they may provide the raw material for industrial research, and further owing to the interdependence of different investigations, progress in any one science may have a very marked bearing on the development of others. Industrial research work in the United States of America, according to Flemming, has developed along certain definite stages:

(*a*) Industrial research applied to the elimination of manufacturing troubles.
(*b*) Research having some new and specific commercial object.
(*c*) Research in pure science with no specific commercial application in view.
(*d*) Research applied to public service.
(*e*) Research for the purpose of establishing standard methods of testing and standard specifications connected with the purchase of raw materials.

Research laboratories in the States are attached to or supported by manufacturing corporations, associations of manufacturers, universities and colleges, national institutions, commercial laboratories and scientific societies.

Apart from numerous endowments and appropriations made for research to various universities, colleges and Government departments, there are in the States a large number of funds that have been established for the endowment of scientific research alone. Though a number of them are for the promotion of industrial research, others were founded for providing the necessary funds for medical, astronomical and general research in other sciences. In 1917 a National Research Council was appointed by the National Academy of Sciences at the request of the President of the United States. This Council includes the most prominent research men in the States and all departments of research are fully represented. Its object is to co-ordinate the scientific research work of the country in order to secure efficiency in the solution of the problems of war and peace, and this Council has rendered possible the nationalization of research in the country. Selection and training of research men have also been given special attention to, and it has been found that 'while full credit should be given to the genius who can often achieve so much with very limited facilities, it is a fallacy to assume that research work of great value cannot be carried out by men of no more than average attainments. This is illustrated by the success achieved in many of the laboratories in the States, where, with suitable organization, important investigations both directly connected with industry and in pure science have been successfully dealt with by men of no more than average ability working under competent direction'.

Industry has rightly been styled as the basis of national prosperity, and it is, therefore, necessary that every resource should be used to facilitate its progress In this connection research is of the utmost importance and it must be regarded as an indispensable weapon with which to develop industries of any country and to cope with international competition.

The National Planning Committee which has been working in Bombay for the past several months is collecting detailed data in regard to industrialization of the country in all its aspects and other national problems, and it is hoped that its work would prove valuable in laying down the lines for future development in the country.

Concluding Remarks: I have given you a bird's-eye view of the organization and development of scientific research and studies in India up to the present day, and of the lines followed in Great Britain for the organization and development of scientific research, both pure and applied, the latter with particular reference to the needs of industry and the life of the people. I have also incidentally referred to the development of similar machineries in Canada, Australia, New Zealand and South Africa, and, finally, to the highly organized system in the United States. On the analogy of these great industrial countries, I give below the outlines of a scheme for developing a similar organization in India to plan and co-ordinate research so as to avoid wastage both of talent and funds, preclude duplication, employ the available scientific personnel to the best advantage, and, finally, to arrange for the training of a much larger number of research personnel to supply the needs of the developing industry.

Starting from the top I consider it absolutely essential that there should be a separate department of the Central Government corresponding to the Department of Industrial and Scientific Research in Great Britain. It should be staffed by scientists with administrative experience and not by civilian administrators; and this I consider to be the absolute *sine-qua-non* of the whole scheme. Civilian administrators, though they are admirably suited to carry on the civil and military side of the Government, have unfortunately seldom realized the exact needs of Science in the country, and as a result the progress of Science in India has been materially slowed down, if not actually hindered. The Department should have an Advisory Council, the National Research Council, constituted on the lines of the Research Councils of other countries for planning and co-ordinating research, to promote and develop not only scientific but industrial research in the country, and finally for devising ways and means to make India independent, so far as possible, of foreign imports by a well-planned survey and development of its economic resources. It is only then that it would be possible for this country to assume its right place among the industrially developed countries of the world. With a view to harnessing Science in the service of Industry, the proposed Department and its Advisory Council will also have to explore ways and means for extending the existing machinery of scientific education in the country, from the school to the university stage, develop applied scientific training and research, and finally to see that research, whether in pure or applied sciences, is undertaken with a definite end in view and not only as a means for self-glorification.

I have only given the broad outline of the scheme, as I am of the opinion that its details can only be evolved after careful consideration of the *pros and cons* by an expert committee on which all elements of science and industry in the country are fully represented Let us hope that this scheme will commend itself to the Government and that steps will be taken at a very early date to bring into being such an agency; this alone will enable the country to steer a safe course in the face of the Armageddon which is now threatening the world.

Indian Flora, its Medicinal and Toxic Properties

Medicinal and Poisonous Plants: For the past twenty years I have been interested in the Indian flora in connection with the medicinal and toxic properties of the different plants and I propose to present to you some of the aspects of this work which are of interest both from the scientific and economic points of view. I have selected this subject as owing to the outbreak of the war, the question of the supply of medicinal drugs in this country has assumed considerable importance, and I feel that a review of this work may help at least towards a partial solution of this vital problem. Further, the significance of the large numbers and wide prevalence of the plants toxic to man, livestock and insects has not so far been fully appreciated in this country, and I hope that this review will stimulate interest in this direction. Vast as the vegetable resources of this country are, I am convinced that they are not being properly exploited to the best advantage of the people of this land.

GENERAL CONSIDERATIONS

Climate and topography: The extreme variability that India presents in its meteorological and climatic conditions as also in its topographical features is perhaps unrivalled in the world. The tremendous range of variation of temperature from 126°F in summer at Jacobabad to −46°F in winter at Dras and the prevalence of arctic conditions throughout the year in some of the Himalayan ranges, rainfall from 430 inches at Cherrapunji in the hills of Assam to less than 5 inches per annum in the desert areas of Rajputana, saturation of air with moisture in the coastal districts and in the hills during the south-west monsoon to periods of practically zero relative humidity in the dry weather during the north-east monsoon, are some of the interesting contrasts presented by the country. No less striking are its physical features. It has the most massive and the loftiest range of mountains in the world, the Himalayas; there are also lower hills and plateaus, extensive rich alluvial plains, sandy wastes and deserts, hill streams, mighty rivers with their extensive deltaic and estuarine systems, numerous lakes, canals, ponds, tanks and extensive marshy tracts, sandy or rocky coasts spread over an area of 1,575,107 square miles. It has in fact been described as an epitome of almost all climates, seasons, and soils of the British Empire. Under these conditions it is not surprising that India has one of the richest and certainly the most varied flora of [illegible] area of similar size on the surface of the globe.

Features of Indian Vegetation: Roughly speaking, one-fifth of the Indian Empire is occupied by forests of different kinds. There are evergreen forests occupying the west coast of the Peninsula up to the ridges of the western mountain chain, and the lower slopes of the Eastern Himalayas, with their magnificent and majestic trees, the 'sky scrapers', and the Carnatic evergreens characterized by the comparatively smaller size of their trees. A large part of the Peninsula is covered by the deciduous type of forests which are very valuable to the country. There are the dry forests of Rajputana and the Punjab which are also spread over a large area of Indian States; these become drier and drier towards the west and south-west and disappear into the deserts on both sides of the lower Indus; there being very little vegetation of any kind in the Great Indian Desert itself. Many tidal creeks and backwaters along the coasts of India, chiefly the deltas of rivers, such as the Sundribans are covered with another type of evergreen forest, the tidal or littoral, where many plants send up from their underground roots a number of aerial roots for respiration The massive chain of the Himalayas with its tropical, temperate and alpine flora presents unique features. The eastern Himalayan flora differs remarkably from the western in several respects in addition to the disappearance of the tropical type as the extreme north-west is reached. It is in this chain that the highest limit of vegetable life on earth has been recorded. The tree limit in the Western Himalayas corresponds roughly with the snow-line, *i.e.*, 12,000 ft. above sea level, above which a variety of beautifully coloured flowers flourish. Aquatic or semi-aquatic types of vegetation are found in the tanks, jhils, ponds, water-courses, and swamps all over India, particularly in Bengal. Lastly, there are areas in the plains, as well as in the hills, especially in the former, which have, through the influence of man in search of more and more agriculturally exploitable land, lost much of their original characters. Another feature of the Indian vegetation is that in one season of the year vast areas in the plains of India are the scene of plenty for man and animals; in another they become a dreary brown sunburnt waste where herbivores starve by the thousands and where it passes human understanding how any creature dependent on plant life can survive the dry season.

Relationship to other floras: The Indian flora is closely related to that of some other countries, and it is interesting to remark that none of the families of flowering plants is peculiar to this country. There is a very great preponderance of those genera and species which are also found in the adjacent countries. Malayan, Burmese and Chinese genera are specially well represented in Eastern India. Next in order come European and middle east floras which are particularly strongly represented in Western India, and of the typically European elements there are twice as many in the Western as in the

Eastern Himalayas. Nearly 600 European genera are represented in India, many of them by a single species, and the middle eastern element is certainly, as is to be expected, no less prominent. African, Australian and American elements follow these in decreasing proportions, the African flora being more noticeable in Western India. Recently there has been an influx of American species, with their remarkable tendency to spread. Tibetan and Siberian floras only reach India in the alpine regions of the Himalayas, while Chinese and Japanese elements are strongly represented in its temperate belts.

MEDICINAL PLANTS OF INDIA

General: India abounds in all kinds of food plants, spices, perfumes, timber, fibres, gums, etc., which have been known all over the world from ancient times There are more than about 700 important fodder plants including about 260 species of valuable fodder grasses It is not surprising, therefore, that plants containing active and medicinal principles also grow abundantly within its bounds. More than 2,000 plants, out of a total of about 11,000 species found in India, are alleged to have medicinal properties of some description or other and have been enumerated in the literature of indigenous medicine. Nearly three-fourths of the drugs mentioned in the British and other Pharmacopoeias grow here in a state of nature and others can be easily grown. Indeed, this country is a veritable emporium of drugs. The families to which the larger numbers of medicinal plants belong are Leguminosae, Compositae, Labiatae, Euphorbiaceae, Rubiaceae, Rosaceae, Gramineae, Liliaceae, Rutaceae, Ranunculaceae, Umbelliferae, Cucurbitaceae, Solanaceae, Apocynaceae and Malvaceae.

It stands to reason that all these 2,000 odd plants cannot have the wonderful virtues attributed to them, but it is believed that there are some of these which might rightly deserve the reputation they have earned as cures. It was to find out what these were that their study was first begun in the early part of the last century. Although many workers including Jones, Ainslie, Roxburgh, O'Shaughnessy, Moodeen Sheriff, Dymock, Watt, Kirtikar and Basu and others carried out laborious investigations, the pharmacology of most of the indigenous remedies remained an unexplored field till recent years.

Medicine is intimately related to chemistry and experimental work on the pharmacological side can only be carried out in laboratories properly equipped with modern appliances. None of these were available in this country till the Calcutta School of Tropical Medicine was established in 1921. Then for the first time proper collaboration between chemists, botanists and pharmacologists was rendered possible, while arrangements for clinical trials of the drugs were made by the establishment of the Carmichael Hospital for Tropical Diseases. Work on medicinal plants was thus started by my colleagues and myself and our first main objective was to make India self-supporting by enabling her to utilize drugs produced in the country and by manufacturing them in a form suitable for administration. There are a number of drugs of established therapeutic value which are in use in the pharmacopoeias of different countries. The majority of these grow wild in great profusion in many parts of India and a certain number are even cultivated. If these resources could be utilized and the finished products manufactured, treatment of many diseases could be brought within the means of the Indian masses whose economic condition is unfortunately of a very low order.

A number of important drugs, extensively used by the medical profession, however, are neither found wild nor have so far been cultivated in India. Cultivation of such drugs is very important from an economic point of view, and scientific research in this direction, as is being carried out in other countries, would be very fruitful. It is a matter of regret that India is still importing large quantities of crude drugs in spite of the fact that practically every conceivable pharmacopoeial drug can be grown within her bounds. The history of the cultivation of cinchona, eucalyptus, digitalis, etc. in India clearly shows that the cultivation of medicinal plants is pregnant with rich possibilities if taken up on proper lines. It is gratifying to note that more and more interest is now being taken in this direction. A list of medicinal plants which might with advantage be cultivated has been prepared and is available for those interested in such development.

Remedies used in Indigenous Medicine: Our second objective has been to discover remedies from the claims of Ayurvedic, Tibbi and other indigenous resources suitable for employment by exponents of Western medicine. Since the period of decay and resuscitation of old systems of Indian medicine, many of the effective remedies have been lost while a number of uncertain ones have crept in. Belief in their efficacy originates in some cases from the teachings of the ancient commentators and is based on clinical data, but in others has no foundation whatever. Nearly two hundred medicinal plants have been investigated in our laboratories and some of these have been shown to be of practical utility. Apart from this, the negative value of such investigations should not be lost sight of. Whatever the merits or demerits of the indigenous systems may be, it should be remembered that they minister to the needs of nearly 80 per cent of the population of this vast country. It is, therefore, the primary duty of any research organization existing in this country to evaluate their effectiveness and practical utility.

Collection of drugs: A few words may be said here with regard to the time of collection of drugs. During the last twenty-five years several drugs of Indian origin have assumed considerable importance from the point of view of foreign trade. Many firms of drug manufacturers in this country also use the locally produced raw materials for the manufacture of the finished products. It is a matter of very great concern, therefore, that the crude drugs collected locally are often not up to the required standard and this has resulted in considerable economic loss Fortunately, this state of affairs is being gradually rectified but I cannot let this opportunity pass without reiterating that collection of drugs is not so simple a matter as most people seem to imagine. Collectors of medicinal drugs growing in a state of nature, and the present and prospective cultivators should bear in mind that there are certain factors which have to be considered in order to obtain the standard product. There is a good deal of variation in the active principles in the different parts of a plant and in different seasons in the same part of the plant. Even the same part and at the same time of the year shows remarkable variations in the contents of its active principles; for example, the young and the old leaves of a plant and unopened and opened flowers differ materially despite the fact that they are collected from the same plant and during the same season. The soil also has an important influence on the active principles of plants. I have often observed in the course of my work that plants collected at the proper time, when the active principles have reached maturity and are at their maximum, give very effective results while the same plants when collected under other conditions are utterly useless. Conditions for the collection of drugs in the case of plants under cultivation are more favourable and strict control over various factors can be exercised with greater case than is the case with plants growing in a state of nature. It has, however, to be admitted that ideal conditions for the collection of even many of the common and important medicinal plants are not known with precision, and research is urgently needed to determine the time when the active principles are at their maximum under the environments existing in this country, as was done by the Dutch in Java in the case of cinchona. If this could be systematically carried out, India could supply the whole of the world with medicinal 'herbs.'

Poisonous Plants

General consideration and loss to India: Intimately connected with the study of medicinal plants is the problem of poisonous plants, but till recently little attention has been paid to this study in this country. They contain chemical constituents which, if introduced into the body of an animal in relatively small quantities, act deleteriously and may cause serious impairment of bodily functions or even death. They injure the basic live principle, the protoplasm, of the cells of which the animal body is built up. They are ordinarily called poisonous plants, and apart from the utilization of their potent properties in the treatment of diseases to alleviate the sufferings of man and animals, there appears to be no doubt that they are a source of great menace in India through poisoning of livestock.

Poisoning of livestock: We are concerned in this country with the welfare of 360 millions of human beings, as well as with that of roughly 220 millions of the bovine population out of a total of about 730 millions in the whole world. Even in its present unsatisfactory condition, the cattle industry contributes roughly about 10,000 million rupees to the annual agricultural income of 20,000 million rupees of this vast country. The importance of plants which are poisonous to livestock will thus be readily understood. It is a matter of regret that no systematic attempt has been made in India so far to investigate these plants on scientific lines with a view to devising means whereby this menace could be controlled. It is also unfortunate that no figures are available of the loss suffered by India through poisoning of livestock by this agency, but it may be interesting here to give the example of two States, Montana and Colorado in the United States of America, which may give us some idea of the possible damage. In that area it has been estimated that the loss inflicted to the livestock industry by plant poisoning is in the neighbourhood of 220 million dollars annually. This is a very high figure considering that the size and extent of these States as compared with India is less than one-sixth, and also considering the fact that the knowledge regarding the poisonous plants there is well advanced and preventive measures are practised. The conditions existing in India can be readily imagined.

Study of Poisonous Plants: With a view to combating this menace, and as a natural corollary to the study of medicinal plants, the study of poisonous plants of India has been undertaken at the School of Tropical Medicine during recent years. This work has brought out some outstanding features of the problem which had not been hitherto appreciated in India. About 700 poisonous species belonging to over 90 families of flowering plants are known. The more important of these in their order of importance are Ranunculaceae, Euphorbiaceae, Leguminosae, Solanaceae, Compositae, Apocynaceae, Asclepiadaceae, Ericaceae, Liliaceae, Gramineae, Araceae, Anacardiaceae, Thymelaeaceae, Rosaceae and Rubiaceae. As in the case of medicinal plants, it does not mean that other families do not contain important poisonous plants. In fact there are several other families which have a few of the very potent species belonging to this group. The above list of the important families merely indicates that they contain the largest number of poisonous plants, so far as is known at present, with a further likelihood of containing plants with potent principles which are at present unknown.

In the case of the majority of plants, poisonous properties are only suspected but have not been substantiated by chemical analyses and pharmacological experimentation. This is now being done, so far as possible; preliminary chemical examinations of a large number of plants have been made and a monograph on the subject is now in press. A thorough and comprehensive study of all these plants, however, would mean sustained work for many years and perhaps for several generations. In the present work we are getting together all the information, botanical, chemical and pharmacological, with detailed references to the literature. This monograph, when completed, should serve as a basis for further work on these plants, the importance of which from an economic point of view cannot be overrated. Increased knowledge with regard to their distribution and the nature of active principles responsible for poisoning is the first step towards controlling this problem by taking preventive measures.

Insecticidal and insect repellent plants: Another aspect of these plants which will repay study concerns those which have insecticidal and insect repellent properties. Losses inflicted upon India by insects are enormous and at a moderate estimate are calculated at 2,000 million rupees annually and over a million and a half of human lives. Effective defence against these enemies of social and economic progress should materially reduce this enormous wastage and facilitate national development. The finding of cheap insecticides for the diverse needs of agriculture, destruction of household pests, prevention of vectors of such diseases as malaria and many others borne by insects, commensurate with the limited means of the great masses in India, are important problems to which little attention has been paid till recently. Vegetable insecticides are preferable to mineral ones, as these are less deleterious to man and other warm-blooded animals generally, and as they are also less harmful from the point of view of agriculture. Lists of the possible insecticidal and insect repellent plants growing in India, and of reputed fish poisons some of which may also act as insecticides have been prepared.

HERBARIUM OF MEDICINAL AND POISONOUS PLANTS

One of the chief difficulties in connection with our work on medicinal and poisonous plants has been the proper identification of the material to be investigated. The descriptions of plants given in the literature on indigenous medicine are meagre and vague and this has resulted in considerable confusion. Many drugs are sold under different names, different drugs under the same name, and even the learned *Kavirajs* and *Hakims* cannot say with certainty which species are meant in the old text-books. No authentic specimens of even the well-known remedies were ever collected and preserved by the exponents of indigenous medicine and no actual comparison is possible. Even with the great advances in systematic botany, expert botanical identification is not infallible and the botanists also sometimes prefer to disagree. Publications of recent botanical monographs show, how with the advance of knowledge our conception of species has varied. Descriptions alone are not always sufficient for settling disputed questions and recourse to actual specimens is often absolutely necessary. It is very important, therefore, to preserve specimens of all plants submitted for investigation, so that these may be available for reference in case any doubt as to their identity arises at a later date. Some of the chemical and pharmacological work done on these plants has been vitiated by carelessness in identification. With a view to combating this state of affairs it was considered desirable to collect authentic specimens of all the plants with alleged medicinal or toxic properties and after proper identification preserve them for the purpose of comparison. This work has progressed and it has been possible to collect 6,000 specimen sheets of about 1,600 species. About 900 species have yet to be obtained to complete the collection of all the known medicinal and poisonous plants growing in India. As most of the more easily available plants have been obtained, the collection of the remainder is becoming more and more difficult but the work is being continued. When this is accomplished, this collection will be the first of its kind in India, and should be an asset both from the scientific and economic points of view. The present collection will, it is hoped, form the nucleus for a national herbarium of medicinal and poisonous plants.

Survey of Medicinal and Poisonous Plants in India: A question of great economic importance is the working out of the distribution of medicinal and poisonous plants in this country. The distribution of many plants as described in literature is often vague and inaccuracies, which have crept in, have been passed down from one publication to another. To this may be added the fact that plants which were found in a particular locality some years ago often do not occur there at the present day. The influence of man in changing forests into agricultural lands and sometimes again abandoning them to the care of nature, together with the competition of plants amongst themselves is materially responsible for the change in the floras of various areas. For this reason we started the stock-taking of the present distribution of medicinal and poisonous plants to work out, as exactly as possible, the present areas of their distribution. All the available literature is being consulted and herbaria all over India are being scrutinized. Personal visits are being paid to different parts of India determine the areas of abundance of these plants growing in a state of nature. The work under this head is very extensive when it is remembered that it deals with about one-fifth of the total number of plants found in India, but this is the only way of estimating with any degree of accuracy whether a certain plant grows well and in abundance or is scarce in a certain area. Valuable information is thus being collected, and this will be of practical value to those interested in harnessing the natural resources of the country. This will also give indications of suitable localities for the cultivation of medicinal plants.

From the point of view of poisonous plants also, this survey is of great practical value, as once the occurrence of the harmful herbage in grasslands and other localities open to grazing for livestock are mapped, it should be possible to adopt measures for the protection of livestock against the menace of poisoning.

CORRELATION OF BOTANICAL CLASSIFICATION OF PLANTS, THEIR CHEMICAL CONSTITUTION AND THEIR PHYSIOLOGICAL PROPERTIES

Active principle and new classification: With the advance of knowledge of the chemistry and pharmacology of plants, it appears to be certain that some correlation exists between the botanical classification of plants, their chemical constitution and physiological properties, and one is frequently struck with the remarkable resemblance exhibited by closely allied plants in this respect. For example, if a particular chemical constituent is found in one member of the genus, there is considerable likelihood of the presence of constituents with identical or similar physiological properties in other members of the genus or of the family. This does not, of course, mean that such similarity will not be found in other families or genera just as particular taxonomic characters may be spread over widely different families and genera. An ideal classification of plants would be the one which in addition to satisfying botanical criteria broadly provides an index to the nature of their chemical constituents and physiological properties. With our existing knowledge this is not possible. The very fact that some of the families and genera, as at present understood, are quite homogeneous in these respects, however, reflects a ray of hope that after all the problem is not so difficult as it appears at first sight. Considerable work on the chemistry of plants and the determination of the physiological properties of their active principles, however, will have to be carried out and thousands of new plants will have to be investigated before this is attained, or the attempt given up as hopeless. This should not, however, be understood to imply that I suggest that advances in the knowledge of chemistry and pharmacology should determine the botanical classification of plants. This is not possible, as such features cannot possibly serve as taxonomic characters. But I do hope that botanists, chemists and pharmacologists will collaborate in evolving a natural system of classification based on their combined efforts.

Chemical Constituents: A brief review of the distribution of the more important and potent chemical constituents of the Indian flowering plants of widely different families and genera presents certain very interesting features. The alkaloids are distributed over about 40 families and there are a number of cases where the same alkaloid is found in closely allied genera and families. Thus, berberine has been recorded from six different families and twelve genera. Ephedrine, on the other hand, furnishes an example wherein a particular alkaloid may be found in plants belonging to widely different groups; it has been found in *Sida cordifolia* Linn. of Malvaceae (a family belonging to Angiospermae) and in *Ephedra* of Gnetaceae (a family belonging to Gymnospermae). Purines are found in three families. The glucosides form a large group and are much wider in occurrence than the alkaloids, occurring both in Dicotyledons and Monocotyledons; some of these are very toxic and occur in eight widely different families. Hydrocyanic acid yielding plants belong to ten families. A group of glucosides known as saponins is of very wide occurrence in the vegetable kingdom; saponins are known from at least 400 plants belonging to 50 different families occurring almost all over the world. Essential oils are of wide occurrence in the vegetable kingdom though certain families, such as Labiatae, Rutaceae, Umbelliferae, Myrtaceae, Lauraceae, Cruciferae and Coniferae are especially rich in these substances. The seeds of numerous plants contain albumins, but it is interesting to note certain plants, such as *Abrus precatorius* Linn and *Ricinus communis* Linn belonging to very different families (Leguminosae and Euphorbiaceae respectively) wherein the toxicity of these albumins is of a similar nature, both being essentially blood-poisons, and both similar in their immunity reactions if introduced into the body of animals in small and gradually increasing doses.

I do not propose to go into further details of several other chemical constituents, nor even of such toxic complexes as resins, phenolic compounds, etc. The few examples cited provide sufficient evidence in support of the now well-established theory of organic evolution. I repeat that there is a method in their occurrence; in several cases it is due to their descent from common ancestors while in others it is a result of parallel evolution. The facts described above cannot be explained on any other basis.

Examples of correlation: I will now cite a few examples of some families and genera to show the marked resemblances between their botanical, chemical and pharmacological aspects. Unless definitely proved as harmless it is advisable, for instance, to regard all members of Ranunculaceae as potentially poisonous, especially when fresh, both for human beings and livestock Poisonous, acrid, vesicant, purgative and narcotic properties prevail in varying degree throughout the family. Species of *Anemone*, *Caltha*, *Clematis* and *Ranunculus* contain the lactone anemonin which has blistering properties. Most of the Aconites contain highly poisonous alkaloids which act mainly on the sensory nerves and on the medulla which they depress and ultimately paralyse. Species of *Delphinium* are used for the destruction of vermin and contain toxic alkaloids, some of which appear to act like aconitine, while others paralyse the motor nerves. Alkaloids are also known to occur in the genera *Coptis*, *Helleborus*, *Nigella*, *Isopyrum* and *Paeonia*. *Adonis* and *Helleborus* contain glucosides with a digitalis-like action. Saponins are found in the genera *Clematis*, *Ranunculus*, *Nigella* and *Cimicifuga*. Cyanogenetic compounds have been reported from some of the members of the family and the Indian representatives from which these principles have been reported belong to the genera *Clematis*, *Aquilegia*, *Isopyrum* and *Ranunculus*. Seeds of *Annona* of Annonaceae have insecticidal properties and are powerful irritants of the conjunctiva. Several species of *Berberis* contain active principles poisonous to fishes and dogs. Many species of *Papaver* have a juice with narcotic properties and contain powerful alkaloids. Narcotic properties are also possessed by some other members of the family Papaveraceae, e.g., *Meconopsis*. Most Crucifers have pungent juices and many have glucosides in their seeds and produce very irritant essential oils; they possess stimulant properties. Several plants of Caryophyllaceae contain saponins. The family Rutaceae is characterized by the presence of essential oils some of which are toxic. Many plants belonging to Sapindaceae have saponins and a number of them are well known as fish poisons. Anacardiaceae are usually provided with more or less acrid resinous, sometimes milky juices; very many species of this family possess astringent properties. Plants of no less than twenty-seven genera of Leguminosae possess insecticidal or piscicidal properties. The poisonous properties of Rosaceae are generally due to the presence of cyanogenetic compounds. The presence of powerful bitter and purgative principles is the prevailing characteristic of the wild members of Cucurbitaceae. Aromatic members of Umbelliferae are usually carminative, while the non-aromatic members are often acrid and narcotic and should be taken with care. Alkaloids with similar physiological properties are the outstanding constituents of the genus *Cinchona*. Lobelias belonging to Campanulaceae yield an intensely acrid milky juice and the dust of the powdered herbs irritates the nostrils in the same way as tobacco; they contain alkaloids. Rhododendrons mask, under the beauty of their flowers, very fatal active principles and the family Ericaceae to which they belong contains several insecticidal plants; the toxic substance andromedotoxin is very common in this family. Apocynaceae includes several plants which are highly poisonous, the properties of most of them being due to glucosides with a digitalis-like action and physiologically active alkaloids. Many species of Asclepiadaceae contain acrid, bitter and poisonous juices. The genus *Strychnos* is rich in alkaloids which are violent tetanic poisons. Many species of Convolvulaceae have an acrid taste and contain active purgative principles. Mydriatic alkaloids such as atropine, hyoscine and hyoscyamine are found in several species of Solanaceae while the glucosidal alkaloid solanin is found in many Solanums and some other genera as well; a very large number of wild plants of this family are poisonous Labiatae is very uniform in the possession of essential oils, several of which are of medicinal value as carminatives and stimulants. Toxic resins are reported from a number of species belonging to Thymelaeaceae and animals avoid eating them. Several species of Euphorbiaceae contain more or less acrid and irritant juices and several species of Crotons contain highly irritant toxalbumins and are drastic purgatives. Urticating principles are found in four Indian genera of Urticaceae. The alkaloids ephedrine and pseudoephedrine are found in a number of Ephedras. Coniferae are characterized by containing essential oils which produce gastro-intestinal irritation and sometimes ulceration. Several species of Dioscoreaceae contain an acrid juice in their tubers and some are even poisonous. Quite a number of species of Araceae contain raphides of calcium oxalate and acrid juices; a number of these plants, if eaten, especially when in fresh condition, produce symptoms of irritant poisoning. Some of the Gramineae, especially when young, wilted or under drought conditions produce hydrocyanic acid and are fatal to livestock; no alkaloid has so far been isolated from members of this family.

Many more examples could be cited, but the brief review of the relationship which seems to exist between the botanical classification and the chemical and physiological characteristics of medicinal and poisonous plants should prove sufficient to show that in many of the families and genera these characteristics show a marked degree of correlation. I do hope that further work will produce increasing evidence of this relationship. The botanical characters, chemical constituents and properties exhibited by plants are all the results of organic evolution and a natural classification must embrace all these three aspects. There is, however, an element of disturbance in the case of plants. Climate, seasons, soil, cultivation, etc., have profoundly affected their chemical composition and hence their physiological characteristics, and it is for this reason also that closely related plants differ in their pharmacological properties.

CONCLUSION

The above brief review of our work on the medicinal and poisonous plants, the difficulties encountered and partially overcome, and indications in regard to their utilitarian and scientific aspects, will, I hope, stimulate interest in this subject which is of considerable economic importance to the country, particularly at the present juncture. Collaboration between botanists, chemists, pharmacologists and agriculturists in work of the type indicated in a country such as India, with all extremes of meteorological, climatic and topographical features resulting in very varied and luxuriant floras of all types is pregnant with possibilities which should not only be of very great scientific and academic interest but also prove of great practical importance to the country from the economic point of view.

ORGANISATION OF PUBLIC HEALTH AND MEDICAL SERVICES IN INDIA

R N CHOPRA

(delivered at Benares, 1941)

Development of research: In my Address last year I briefly discussed the organization and development of scientific studies and research in India and incidentally referred to the organizations which had been started for the development of scientific research in Great Britain, various British Dominions and the United States of America. On the analogy of these organizations in some of the most highly developed industrial countries, I suggested the outlines of a scheme for developing and co-ordinating scientific research in India so as to employ the available talent and funds to the best advantage and, finally, to train a much larger and adequate research personnel for supplying the needs of various industries. It is unfortunate that nothing like a comprehensive scheme for the development and co-ordination of scientific resources and research in the country has been taken up so far. The outline of the scheme suggested in my Address last year was for a body which could draw up a comprehensive plan of scientific and industrial research, mobilize all available talent in the country by alloting problems to scientists and institutes best suited for their solution, provide necessary research facilities and adequate grants, and finally deal *in extenso* with all scientific and industrial problems of the entire country. This alone could result in the industrial development of the country on a scale which would make it possible for India with its untold wealth of raw materials to become independent, so far as possible, of foreign imports, and provide for its scientists the opportunities of carrying out work of real service to the country. Owing to the stress of war conditions and the lack of funds for the necessary capital outlay which such a scheme would involve no comprehensive scheme has been evolved, but the establishment of a Board of Scientific and Industrial Research by the Central Government is a move in the right direction.

Board of Scientific and Industrial Research: This Board has been instituted by the Government of India for an initial term of two years in the first instance. It has centralized responsibility, created a directing agency, and a sum of 5 lakhs of rupees has been placed at its disposal for subsidizing research. The sum is extremely inadequate and is a microscopic quantity compared with the large sums spent in Europe and America on Scientific and Industrial Research. One of our distinguished Fellows, Dr S S Bhatnagar, a well-known chemist, has been appointed as its first Director, and the Government Test House, Alipore, Calcutta, has been placed under his charge for carrying on direct research on problems not assigned to other institutions or scientists. It is to be hoped that this institution will soon develop into the National Chemical and Physical Laboratories, each under its own Director, and be able to deal with the multifarious problems connected with industrial research in the country. The Board has carried out an initial survey of the industrial research activities in the country, and work has already been started in various centres on a number of urgent problems. With the concurrence of the Government, the Board has appointed six Research Committees to deal with problems connected with vegetable oils, fertilizers, drugs, plastics, sulphur, and scientific instruments. In addition six exploratory committees for investigating possibilities of research in connection with the graphite, carbon and electrodes, molasses, glass and refractories, vegetable dyes, fuel and cellulose have also been appointed Grants-in-aid amounting to about 3 lakhs of rupees were sanctioned in the first meeting, and further schemes for grants-in-aid are under consideration by the Board

Drug control in India: Drug production and drug trade have been entirely uncontrolled in the country so far. That both the manufacturers and the consuming public have suffered from the lack of such a control had been patent to all concerned, but the exact position was not realized till the Drug Enquiry Committee under my direction submitted its detailed report in 1931. After 9 years the Drugs Act was passed by the Government of India in 1940. This Act is intended to regulate the import, manufacture, distribution and sale of drugs, and should materially help in the development of the drug industry in this country along right lines. It provides for the formation of a Central Drugs Technical Advisory Board and of a Drugs Consultative Committee representing the different Provincial Governments. The first agency will frame uniform rules, establish standards, which require considerable expert technical knowledge and research, provide a central organization for testing and analyzing drugs and in general be the agency for controlling the manufacture of drugs of standard strengths in the country. The second agency will enforce the provisions of the Drugs Act in the different Provinces uniformly. After the framing of the necessary rules by the Central Drugs Technical Advisory Board and the Drugs Consultative Committee, the Provincial Governments will, it is hoped, set up Provincial Advisory Boards and testing laboratories in their respective provinces for the control of the drugs trade in their areas. The steps which have been taken so far are undoubtedly far reaching, but only a start has been made, and I hope that before long the machinery will start working. As a result not only the drug manufacturers, but the public also will benefit from the proper standardization and control of this very important, but greatly neglected, industry. This is particularly important at the present moment when owing to the war the import of drugs from foreign countries has been materially reduced, while the demand remains the same, if it has not actually increased. Manufacturers of drugs in India have been slow in not taking advantage of the golden opportunity offered by the unfortunate position created by the war in Europe. My only hope is that manufacturers in the country will realize their great responsibility, and taking advantage of the existing conditions utilize to the fullest extent their chances of establishing a stable drug industry in this country which alone will enable them to produce every conceivable medicinal preparation, synthetic or otherwise.

Agricultural Research: The Central Legislature has, during the year under review, passed a bill for financing the work in connection with agricultural research in the country. This welcome measure will provide the Imperial Council of Agricultural Research with the necessary funds for carrying on its multifarious activities. The Governing Body of the Imperial Council of Agricultural Research has provisionally set up a Finance Committee to scrutinize the Council's annual statements of income and expenditure and submit recommendations to the Governing Body. This new Committee, it is also proposed, will examine estimates of all schemes involving an annual expenditure of Rs 10,000 or of a total expenditure of Rs 50,000. The Committee will also consider proposals for new posts in the higher cadres under the Imperial Council of Agricultural Research. Another step of far-reaching importance in the development of agriculture and animal husbandry was decided upon by the Governing Body of the Imperial Council of Agricultural Research at its last Annual Meeting at Simla. It had long been felt that much of the labours of scientists and research laboratories will have little value until steps could be taken to carry the results of their labour to the cultivators in a manner which could be readily and easily understood by the uneducated and untrained agriculturists. It must be admitted that hitherto the scientists on the staff of the Imperial Council of Agricultural Research and other institutions in the country have concentrated primarily on research without an agency to arrange for a direct contact with the cultivators, and thereby giving them in a simple but really effective way the full value of their field and laboratory experiments in connection with the improved methods of farming. The Governing Body of the Imperial Council of Agricultural Research have, therefore, decided on the establishment of a Central Agricultural and Livestock Economic Committee to link up research with practical requirements. The function of this Committee will be to balance the needs of research with those of development, thus making it possible to apply promptly and economically the results of research to practical agriculture and animal husbandry. This Committee, apart from carrying out a preliminary survey of India's needs in the fields of agriculture and animal husbandry, will fully scrutinize all problems of research from the points of view of their practical utility for improving the existing conditions. All these developments are steps in the right direction, and I hope that the Governments, both Central and Provincial, the scientists and the public will co-operate towards improving the present very backward condition of agriculture and livestock, which, with its undeveloped industries, are mainly responsible for the impoverishment of this great land.

National Planning Committee: Reference may also be made at this stage to the labours of the National Planning Committee of the Indian National Congress which has been sitting at Bombay for the last two years under the distinguished Chairmanship of our national leader, Pandit Jawaharlal Nehru. The object of the Committee is to study the problems of the country's poverty, in an objective manner and devise ways and means for increasing the national per capita income from its present extraordinarily low level of Rs 65 per capita per annum to a reasonable figure within the next ten years by the development of agriculture, by large scale industrialization, and evolve a better society by proper training of its citizens and by a proper distribution of wealth. Investigations on such a scale into the country's economic and sociological problems have never been undertaken, and it is gratifying to learn that the Committee was able to impress into its service more than three hundred of the country's foremost scientists, economists, industrialists and public men. We understand that about 21 of the 29 committees have already submitted their reports; these have been discussed by the National Planning Committee and resolutions have been taken on them. Let us hope that whatever be the outcome of the present struggle, the deliberations of these committees will act as guides for the administration in the future handling of the economic and social problems of the country.

Handicaps of scientific workers: India within the past 50 years or so has produced a number of outstanding men in various branches of science, and they have enriched their respective subjects with brilliant discoveries, but unfortunately mostly due to financial reasons their opportunities have been limited and their spheres of work greatly circumscribed; in most cases they have had to work under serious handicaps which no amount of brilliance or hard work could surmount. This view is borne out by Prof Bernal's illuminating remarks in 'The Social Function of Science':

> 'The older civilization of the east had, it is true, learned men, but they followed the established traditions which were for the most part on a level, and largely identical, with those held in Europe at the beginning of the Renaissance Here science was suddenly and abruptly introduced along with other trappings of the more potent industrial civilization. The development of science in non-European countries differed greatly according to

the degree of political and economic control held by the imperial powers . In India there had been a long and unbroken, though lately decadent, tradition of science. The Indian mathematicians had made notable contributions to the general development of mathematics. With English rule new ideas and new methods of education were introduced, but they were introduced in opposition to the older learning, and resulted at first in a more definite split between traditional and foreign knowledge. Moreover, the education introduced from Britain was far more classical and literary than scientific in character.

'Effectively science in India only began in the twentieth century We can say with certainty that there are latent in India great possibilities for scientific development, the mathematics of Ramanujan and the physics of Bose and Raman have already shown that Indian scientists can reach the first ranks Nevertheless, the difficulties under which Indian science suffers will preclude, as long as they last, any large scale development, or, more particularly, any serious influence of science on Indian culture It is inevitable that in science as in other aspects of life the Indians should feel the need for national self-assertion, but this attitude is always an uneasy one . ...

'Needless to say, Indian science, like everything in India except the English Civil Service and the Army, is starved of funds. The total annual sum available for scientific research in India is probably not more than £250,000, which would be equivalent to 1/50 of a penny per head of population, or 0·015% of the miserable national income of £1,700,000,000. Yet there is hardly any country in the world that needs the application of science more than India. In order to release the enormous potentialities for scientific development in the Indian people, it would be necessary to transform them into a self-reliant and free community '

Applying to Indian science what a great Viceroy of India said at one time about the Indian Press, it may be stated that Indian science is very much of an exotic which claims and needs, from the hands that planted it in this somewhat alien soil and clime, full protecting shelter and fostering care. Like European education, modern science in this country was an exotic planted very recently, rather hesitatingly and a little too reservedly, and though the young saplings received a certain amount of protecting shelter, fostering care which was essential, was certainly not extended to them on a scale which alone would have made it possible for the tender plants to become acclimatized and flourish. As a result the growth of these tender saplings has not only been greatly stunted but fortuitous. If science is to play its proper part in the life of the country and the nation, it must receive more generous consideration not only at the hands of the Governments, both Central and Provincial, but also be supported generously by the public, the commercial and agricultural magnates and all those who have the means to help; this alone will make it possible for India to assume its proper place in the scientific world and the comity of commercial nations.

Organization of Public Health and Medical Services in India

The Indian Empire, excluding Burma and Ceylon, extends from Persia and Afghanistan on the west to the borders of China on the east, and from about latitude 40° in the north to almost the equator in the south. This vast area, which presents a land of very varied contrasts in almost all respects, such as its physiography, climate, flora, fauna, anthropology, history, etc., came under the influence of European civilization at a relatively late date, but very material advances in almost all directions have resulted from this contact. Even in regard to this influence, however, the contrasts presented in different parts of the country bring out very vividly the vast nature of the extremely varied problems which had and have to be faced in the length and breadth of this great sub-continent.

Confining my remarks, as I propose to do in this communication, to the Public Health and Medical Services in this country, it is apparent that side by side with the most modern, up-to-date and efficient machinery which has been evolved and established in a number of centres throughout the length and breadth of the country, the state of affairs in many of the areas is almost as primitive as it was during the Moghul times or even earlier. During the early times there was a relatively highly evolved system of curative medicine in vogue throughout India. This was particularly well developed during the heyday of Buddhism in the country, but the highly important preventive side was, as in almost all other countries during this period, non-existent. Contact with the West marked a material change, and one of the outstanding points of this change was that with the exception of a relatively small number of private practitioners of the indigenous systems of medicine, the State assumed almost the entire responsibility for providing medical relief to the country. Hospitals, dispensaries and other adjuncts, together with the necessary personnel, were provided on a fairly liberal scale, but these were far from sufficient for the teeming millions of this great land. Further, in essentials all this provision concerned itself for a long time with the curative rather than the preventive side of medical relief. Within recent years in a few of the larger towns some public-spirited people or communities have provided additional institutions of curative medicine, while the numbers of private practitioners have also materially increased. All the same, the present position is far from satisfactory, and in view of the impending constitutional changes it is proposed in this communication to take stock of the situation and suggest what should be done for improving the existing conditions.

Landmarks in Public Health Administration in India

In a review of the Public Health Administration in India at least three landmarks in the history of its development have to be considered*:—

I. *The appointment of a Royal Commission to enquire into the health of the army in India in 1859.*

II. *The report of the Plague Commission in 1904 following the outbreak of plague in 1896.*

III. *The Reforms introduced by the Government of India Act of 1919.*

The Royal Commission of 1859 was appointed to enquire into the extremely unsatisfactory conditions of the health of the army in the country. Between 1859 and 1863, the mortality rate among European troops was 69 per 1,000, while among European women in 'married quarters' it varied from 44 to 276 per 1,000. The Royal Commission recommended measures not only for the army but also for the civilian population. In accordance with its suggestions 'Commissions of Public Health' were established in Madras, Bombay and Bengal in 1864. The Commissions in Madras and Bengal, though they advocated far-reaching measures including the employment of trained public health staffs in the districts, did not lay down any definite policy. In the words of a former Sanitary Commissioner with the Government of India, 'Government had to deal with a population which was unwilling and unready to receive sanitation, which either frankly disbelieved in its efficacy and resented any change in established customs or was too ignorant and apathetic to understand the goal at which it aimed. Sanitary measures were received not only by indifference but by active opposition'. Under the circumstances, very little advance was possible, but the outbreak of plague in 1896 raised issues of fundamental importance which can best be summed up in the words of the Sanitary Commissioner at that time:—

> 'When plague appeared it was not a new disease, but it was new to the present generation in Indians and it has exacted a very heavy toll of deaths all over the country. The strangeness of the disease, the unpopularity of the measures taken to control it and the importance of these measures have served to rouse the people from their apathy and concentrate the attention of all, but especially of the educated classes, on sanitation in a way that nothing else could have done.
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> 'At the same time plague has not been without its effect on Government. Previous to the advent of this disease it had been the generally accepted opinion that sanitation was the work of any medical officer and required no special training A special sanitary staff had, therefore, not been considered of any very great importance. When plague appeared the staff was inadequate and unprepared; action was taken on general principles and sanitary measures

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*Raja KCKE 'A Plea for a Forward Health Public in India.' *Ind Med Gaz*, July, 1937.

were adopted, which, with further study of the aetiology, we now know were unsuitable and could do little to check the spread of the disease The waste of life, time, money and effort that resulted has impressed on Government the necessity of being prepared in future and large changes have been effected with that object.'

The report of the Plague Commission in 1904 advocated the reconstruction of the Sanitary Department on a wide imperial basis, with the provision of adequate laboratory accommodation for research, teaching and the production of sera and vaccines. The Indian Research Fund Association was formed in 1911 and a forward sanitary policy, with a devolution of powers to the local governments, was formulated in a resolution of the Government of India in 1914.

The Montague-Chelmsford Reforms of 1919 had a very marked effect on Public Health Administration; this was partly beneficial and in other respects detrimental. Provincial ministers responsible to the legislature were anxious to hasten the growth of education, medical relief and sanitation so far as funds permitted. The organization of trained Public Health staffs for urban and rural areas, which the 'Commissions of Public Health' had recommended in the sixties of the last century, was at last taken up in earnest and in the years succeeding the introduction of the Reforms, the organization of health services became a marked feature in most Provinces. Since 1921 there has indeed been far greater public health activity in the Provinces than ever before.

All Civil Medical Services in Presidencies and Provinces were formerly under the control of a single administrative officer known as the Surgeon-General in the former and the Inspector-General of Civil Hospitals in the latter. Unfortunately, owing to an insistent demand for medical relief, which is what appeals most to the individual in a community with a relatively low standard of living, the available funds were expended in the main on increasing and improving hospitals and dispensaries, and the obvious need for more and yet more of these, associated with a chronic shortage of funds led to the neglect of preventive measures and particularly of those fundamental but costly ones comprised in the term 'Environmental Hygiene'. Relief of sickness and suffering was readily understood and appreciated by the public, while the application of sanitary measures, implying as it did interference in age-long habits, with restrictions which were regarded as irksome and trespassing upon vested interests or religious customs, was opposed on all hands by the people who are as conservative as any in the world. *En passant* it may be noted that the position in India at this time was generally very similar to that in England some hundred years ago.

Separation of Preventive and Curative Departments

Early in the present century the Secretary of State for India caused the separation of preventive from curative medicine by creating in each Presidency and Province a separate 'department' for preventive medicine, with an independent budget, and under an officer designated as the 'Sanitary Commissioner'; the name of the officer was changed in 1922 to the less appropriate one of 'Director of Public Health', and his department was also designated as the 'Public Health Department'. In many Provinces the division of duties as between the heads of the departments of curative and preventive medicine was not fully specified, and only a broad distinction of curative and preventive medicine was regarded as sufficient. The formation of separate departments for preventive medicine in the various Provinces provided a great impetus for this branch of medical work, and far-reaching, much needed reforms were planned. These in many cases were well advanced when the Great War (1914-18) called a halt for the time being. After the war the young Public Health Departments again got busy. They found themselves faced with the immense problem of Environmental Hygiene in a land where, even in towns, safe water supply and sanitary systems of sewage and rubbish disposal were, as a rule conspicuous by their absence, the housing of the poorer classes was atrocious, and local administration, except in a few outstanding cases, was overshadowed by vested interests and correspondingly inefficient. In the rural areas sanitation simply did not exist, soil pollution was general, flies swarmed, malaria and hookworm infection were almost universal, leprosy and tuberculosis were widespred, and small-pox, cholera, and plague regularly took their periodic tolls uncontrolled by any environmental checks or preventive measures. The provision of properly qualified and trained staff for this work presented a serious difficulty. The Medical Department had its system of hospitals and dispensaries manned by Civil Surgeons, Assistant Surgeons, and Sub-Assistant Surgeons In some Provinces the Civil Surgeons, originally ex-officio District Medical and Sanitary Officers, retained the dual charge, while the Public Health Department was building up a subordinate personnel of Sanitary Inspectors, epidemic Sub-Assistant Surgeons or Health Assistants to Civil Surgeons and later Health Visitors All these worked under the Director of Public Health who had one or more Assistant Directors and other specialists, leaving the provision of the more costly full-time District Health Officers until the subordinate personnel had been trained and appointed. Other Provinces hastily appointed expensive District Sanitary Officers, whom in some cases they called Medical Officers of Health, although, owing to the fact that every district already had a District Medical Officer or the 'Civil Surgeon' as he is usually called throughout India, their duties were not comparable with those of Medical Officers of Health in England. Further, in the absence of a separate staff of subordinates the work of these new officers was limited to advising only. As an exception, however, the Presidency of Madras succeeded in creating a complete staff of Health Officers, Assistant Officers and Sanitary Inspectors.

Lack of co-operation between Medical and Public Health Departments

The question at the present time is the lack of co-operation and consequently of co-ordination obtaining in many parts of India between the official Medical and Public Health Departments.* This is a problem peculiar to India, for it does not exist in Western countries nor in the Dominions and Colonies where the separation of the official Health Services into 'curative' and 'preventive' sections has never been effected. To some extent this is due to the unsuitable titles given to the respective Departments and still more to their administrative heads In the Presidencies the head of the Medical Department, as has been remarked already, is known as the 'Surgeon-General' : a passable appellation with an historical basis as it is applied to the Chief of the United States Public Health Service. In the Provinces, on the other hand, the head of the Medical Services is known as the 'Inspector-General of Civil Hospitals': an inadequate and misleading designation for one who is the adviser to Government on all matters connected with medical relief, administrator of all public medical institutions, head of the medical services in the Province, President of the Provincial Medical Council of Registration and Medical Education and President or Chairman of a host of other medical organizations and committees. The designation 'Director of Public Health' is equally inappropriate, since it implies extensive powers and a range of activities much wider than are possible under existing conditions. The two titles together are largely responsible for the confusion of functions pertaining to the two Departments and the consequent overlapping, duplication and wastage of their resources. Another factor contributing to this confusion has been the absence of orders laying

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*Jolly, CC 'The need for co-operation in the Medical Health Services of India, with special reference to Maternity and Child Welfare.' *Ind Med Gaz,* April, 1940.

down the exact policy and scope of work for each Department.

It has been asserted that the maintenance of separate departments for medical relief and preventive medicine is an advance upon the English System. Its advocates point out that it enables experts on each side to administer their own subjects. While the specialists in preventive medicine argue that those who have not taken a diploma in Public Health cannot appreciate the requirements and scope of their work, they seem to lose sight of the fact that Public Health personnel is so fully occupied with Environmental Hygiene that it loses all touch with clinical work and is, therefore, not the proper agency for the administration of medical relief. There is much to be said on both sides. Even in England similar views have been expressed by recognized leaders of the profession. But in actual practice the maintenance of two separate public medical services has not led to satisfactory results in India. So long as the Public Health Department limited its activities to Environmental Hygiene there was little or no difficulty. This subject offers so vast a field that it could well keep a large department fully occupied for many decades to come. As soon, however, as the separate Public Health Department proceeded to interest itself in individuals rather than communities, overlapping began to appear; this has been most marked in the fields of maternity and child welfare, leprosy and tuberculosis, and even rural medical relief. In regard to midwifery a tendency appears to be developing which, if it is not checked may lead to a conflict between the practising doctors and health visitors and midwives. Already with the peculiar social conditions prevailing in this country medical colleges and schools are finding it increasingly difficult to obtain the requisite number of 'cases' for training. The position in regard to such diseases as leprosy and tuberculosis is anomalous. In one Province the Inspector-General of Civil Hospitals is responsible for leprosy work, in another the Director of Public Health The same is the case with tuberculosis.

There is sufficient evidence, where it occurs, of a lack of co-operation between the two official departments and of the development of 'exclusion' instead of an *esprit de corps* which can only be destructive in its effects. The situation requires to be met by a close *liaison* between the two branches, such as, for example, obtains in the Government of India, where the Director-General, Indian Medical Service, has the Public Health Commissioner working with him in his office as his principal staff colleague Such an arrangement not only conduces to a close co-operation, but the distribution of work is facilitated. The urgent necessity for a friendly collaboration between the two departments, if the system is not to break down, is essential, and is recognized by experienced administrative officers of both departments. The Central Advisory Board of Health, established in 1937, should prove a valuable agency in this direction. At its meeting in Madras in January, 1939, it passed the following resolution for the establishment of similar Provincial Boards of Health·

> 'The Board stresses the desirability of establishing in each Province and State an Advisory Board of Health with the Minister-in-charge as Chairman.'

While in reference to Maternity and Child Welfare it adopted the following resolution:

> 'Co-ordination between the medical and public health departments is perhaps more vital in the field of Maternity and Child Welfare than in any other of medical and public health work.'

If a policy of close friendly collaboration obtains between the two departments in the Provinces and the relative spheres of each are defined, the existing system will continue to function tolerably well, but if friendly co-operation that should be sought and loyally observed by the workers in both the departments is replaced by a spirit of exclusion, and co-operation is stigmatized as a 'dual control', then a position in which the two departments are in opposition will arise sooner or later and the profession will be divided into two camps. Such a state of affairs will hardly be in the interest of either of the two departments, while the effects of such a controversy are bound to lead to a great deal of suffering for the poor public

Federal Ministry of Health

The best solution of the problem appears to be the establishment of Ministries of Health in various Provinces modelled on the English System with suitable modifications in regard to the local conditions.

The modern Public Health Service in England is barely a quarter of a century old and, like so many of the English institutions it arose more by accident than by design. The dissolution of the monasteries left the destitute without any visible means of support until the year 1601, when the Elizabethan Poor Law established Parish Overseers and Workhouses—this system remained practically unchanged for over two centuries. Besides relieving destitution, these authorities carried out any measures that were necessary for the public health, such as the control of epidemics, the provision of sewers, or the abatement of sanitary nuisances. In 1834 the Poor Law Amendment Act. was passed after a great deal of agitation and following the Report of the Poor Law Commission of 1832. This important Bill amalgamated the separate Parishes into Unions under the control of Boards of Guardians. District Medical Officers were appointed to attend to the sick poor, while the infirmaries were built to accommodate paupers who were too ill to be kept in the Workhouses. In 1835 the Municipal Corporations Act was placed on Statute Book to reform the chaotic state of the Borough Government.

Despite all these changes, the state of the public health was never taken very seriously until the cholera epidemics between 1830 and 1854 galvanized the Government into action. Edwin Chadwick, one of the Poor Law Commissioners, in his *Survey into the Sanitary Condition of the Labouring Classes of Great Britain*, exposed not only the insanitary evils of the towns and villages, the hideous legacy of the Industrial Revolution, but, by showing how closely disease was related to poverty, provided a convincing argument in favour of far-reaching reforms. His 'sanitary idea' led to the appointment in 1848 of the General Board of Health, which, after a stormy life, was superseded by the Local Government Board of 1871. In 1872 the country was divided into urban and sanitary districts, and medical officers of health and inspectors of nuisances were appointed for the first time. Credit is due to the authorities of the Liverpool Borough for having had the vision to appoint a Medical Officer of Health much earlier. Then followed the great Public Health Act of 1875 which is the bulwark of all sanitary laws.

A further Municipal Corporation Act was passed in 1882, while the year 1888 was conspicuous for the creation of County Councils and County Borough Councils. From this time onwards there has been an ever widening stream of health legislation. Statute after statute has swollen the ranks of the Public Health Service to such an extent that to-day there is scarcely any field of human activity in which the health officer does not play an important part. Another important landmark, the National Health Insurance Act of 1911, provided the adult manual worker with compulsory insurance against loss of health. The Bill was hotly contested during its passage through Parliament, but it was successfully piloted and passed into law through the efforts of Mr. Lloyd George.

Finally, the creation of a Ministry of Health in 1919 in place of the Local Government Board was the crowning recognition of the importance of health in the nation's life. This wise step was made inevitable by the Great War of 1914-18.

The general powers and duties of the

Minister in relation to health are defined in the second clause of the *Ministry of Health Act*, 1919, as follows: "To take all such steps as may be desirable to secure the preparation, effective carrying out and co-ordination of measures conducive to the health of the people, including measures for the prevention and cure of diseases, the avoidance of fraud in connection with alleged remedies therefore, the treatment of physical and mental defects, the treatment and care of the blind, the initiation and direction of research, the collection, preparation, publication and dissemination of information and statistics relating thereto, and the training of persons for health services"

Ministry of Health: The Ministry of Health is the chief tribunal for Local Authorities. Broadly, it engages in the following activities:—

(1) Public Health.
(2) Local Government and Local Finance.
(3) Housing and Town Planning.
(4) Poor Law Administration.
(5) National Health Insurance.

'Power,' remarked John Stuart Mill, 'may be localized, but knowledge to be most useful must be centralized.' Thus, while most executive functions are passed over to the Local Authorities, the Ministry seeks to maintain proper standards of efficiency amongst them. It supervises their methods of government, especially in regard to the public health matters. Certain too forward authorities have to be restrained, while other backward ones have to be spurred on to better achievement. One of its most important functions is the control of local expenditure by sanctioning loans after careful inquiry.

Its Medical Department, under the Chief Medical Officer, is divided up into the following sections:—

(1) Medical Intelligence, Infectious Diseases, International Health, etc.
(2) Maternity and Child Welfare.
(3) Tuberculosis, Venereal Disease and Institutional Therapy.
(4) Nutrition, Food and Drugs Administration, London Hospitals, Water Supplies, etc
(5) General Practitioner Services and Insurance.
(6) Surveys, Hospitals, Environmental Hygiene, and Public Assistance.
(7) Medical Services, Emergency Hospital.
(8) Welsh Board of Health.

Each of these Divisions is in charge of a Senior Medical Officer who is responsible to the Chief Medical Officer for the work carried on in his division Furthermore, Regional Medical Officers are employed to supervise the work of the panel doctors and the pharmaceutical chemists under the National Health Insurance Scheme, while other officers are detailed to investigate serious epidemics of infectious diseases, outbreaks of food-poisoning, or make surveys of Local Government areas. These surveys are extremely valuable Not only do they provide comparative indices to enable the Ministry to issue reports, circulars, and memoranda for the information and guidance of Local Authorities, but, incidentally, they help the Medical Officer of Health to overcome some of the more difficult problems of administration.

Proposed Federal Ministry of Health of the Government of India

In India a Federal Ministry of Health should be established at the centre to provide the necessary co-operation agency for the provincial local self-government departments, which are at present responsible for the supervision of local bodies and for public health administration in the provinces. This Ministry would also be responsible for the other health functions statutorily conferred on the Central Government by the Government of India Act of 1935. All problems in connection with curative and preventive medicine should be dealt with by one department divided into appropriate sections. The following sections are tentatively suggested for consideration:—

1 Prison medical service.
2. Port sanitation and quarantine service.
3. School medical service.

4 Public Health including
  - (*a*) Medical intelligence, infectious diseases and international health.
  - (*b*) Nutrition, Food and Drugs administration including biological products.
  - (*c*) Environmental Hygiene including housing, water supply, drainage, waste products.
  - (*d*) Industrial hygiene.

5. Medical relief including:
  - (*a*) Maternity and Child Welfare, venereal diseases, tuberculosis, leprosy.
  - (*b*) General practitioner services with special reference to rural dispensaries.
  - (*c*) Hospitals.
  - (*d*) Drug addiction.
  - (*e*) Health Insurance.

6. Lunacy

7. Scientific Research.

For these purposes, the Ministry should have a highly trained staff of expert advisers. The Director-General, Indian Medical Service, who as the Surgeon-General with the Government of India most nearly corresponds to the Chief Medical Officer of the Ministry of Health in England, has at present an insignificant number of specialists on his staff. In England though public health administration is established on well-regulated lines, the Chief Medical Officer controls a strong team of workers in each special subject of medical health work, such as maternity and child welfare, tuberculosis, industrial hygiene and so on In India, on the other hand, while the conditions are much more complex, and although the necessity for an expansion of the Central Government's technical staff has been repeatedly stressed by the Directors-General and Public Health Commissioners, the task is left to only two or three officers.

The materials for the establishment of a Ministry of Health at the centre in India are all available. Thus, though many of the bureaux are under private bodies, their directors act as advisers to the Director-General, Indian Medical Service, who, as a rule, is connected with such bodies as the Chairman of their Managing Committees. Thus with the Director-General at the top we have roughly:—

1. Public Health Commissioner	Bureau of Quarantine, Infectious Diseases and International Health.
2 Deputy Director General	Personnel and Establishment, Medical Relief, Medical Education, etc.
3. Assistant Director-General(Stores)	Medical Supplies.

4 Maternity and Child Welfare Bureau of the Indian Red Cross Society.
The Director-General is the Chairman of the Bureau.

5. Medical Commissioner of the Tuberculosis Association of India.
The Director-General is the Chairman of this Association.

6 Medical Research
The Director-General is head of the Medical Research Department and Chairman of the Scientific Advisory Board, Indian Research Fund Association, while the Public Health Commissioner acts as its Secretary.

7. Drugs Control.
The Director-General has the Director of Drug Control Laboratories on his staff. and he is also the Chairman of the Advisory Board for Drug Control.

8 Nutrition—
The Director of Nutrition Research Institute as the Officer-in-Charge of the Nutrition Enquiries of the Indian Research Fund Association, acts as the expert adviser to the Director-General.

9 Malaria
The Director of the Malaria Institute of India acts as the adviser to the Director-General

Other loose connections exist or are being forged, *e.g.*, leprosy through B.E.L.R.A.: food standards through a standing committee to be set up by the Advisory Board of Health, while new connections have to be established with the Railway Medical Services, Prison Medical Services, School Medical Services, etc.

The provision of a suitable staff of experts must devolve on the Federal Government and cannot be relegated to the provinces. The Royal Commission on Health in Australia (1925) emphasized that, as 'the success of health administration is more dependent on the personality and capability of the officers directing it than on any other single factor, the Commonwealth Government should be responsible for the maintenance of highly trained experts to advise and help local authorities when desired by State Health Administrations'. If such an arrangement has succeeded in Australia, I agree with Raja (1937) that a similar plan might be equally successful in India. Moreover, a carefully selected central staff would, to some extent, avoid the duplication of posts of highly specialized men in the component States of the Federation, while the position and prestige of the Federal Administration should enable it to attract the proper type of men.

The selection of the Federal Chief Medical Officer should, however, be dependent on his having both Medical and Public Health experience, and his deputies must be given a chance to familiarize themselves with the wide range of the curative, preventive and constructive aspects of medicine in the country.

Public Health Organization in the Provinces

Each province should have a Chief Medical Officer responsible to the Minister of Health of the province for the administration of the whole of the medical subject with a number of deputies in charge of the various departments, *e.g.*, prisons, schools, medical and public health problems. The deputies should be given a chance to work in different departments so that the Chief Medical Officer of the future would have men available with firsthand experience of individual and Environmental Hygiene, while Regional Medical Officers should be appointed to look after various areas or zones.

A Provincial Board of Health under the Chairmanship of the Minister of Health should be constituted in each province. The members should be drawn from the Medical and Public Health specialists and suitable persons should be co-opted for different problems. The help of the Revenue, Education and Public Works Departments would be needed to shape the health policy of the Provinces. Suitable persons may be constituted into *ad hoc* committees to tackle important problems of general and local interest, while the co-operation and advice of the specialists on the staff of the Federal Ministry of Health should be available to the Provincial Governments in connection with problems of an all-India nature.

In the districts, District Health Committees should be formed for the same purpose. These should be presided over by the Collector of the district or the President of the District Board; the co-operation of both agencies is essential, and this alone will make it possible for these committees to work efficiently

So far as the rural population is concerned, medical men engaged in curative work should be able to undertake public health duties as well. Their education and training should be of such a nature as to enable them to do so without difficulty. The doctors engaged in combating epidemic diseases should be expected to undertake public health work when not dealing with outbreaks of infectious diseases. The rural doctor, who is the final link between the Health Services in this country and the people, should also be responsible for giving an elementary health education to the patients in connection with their immediate surroundings. Such instruction would be much more effective than general lectures and demonstrations to large audiences

Conclusions

To sum up the views expressed above, I consider that, under the conditions prevailing in India at present, the State is essentially responsible for providing the necessary agencies for both preventive and curative medicine. Curative medicine forms an integral part of the public health services of a country inasmuch as very often the sick man is the source of infection and no constructive medicine is possible unless the population is rendered free from disease by treating the individuals. Again, according to the newer conceptions of a State, it is necessary that disablement whether temporary or permanent should through intensive use of curative medicine be cut down to the barest minimum.

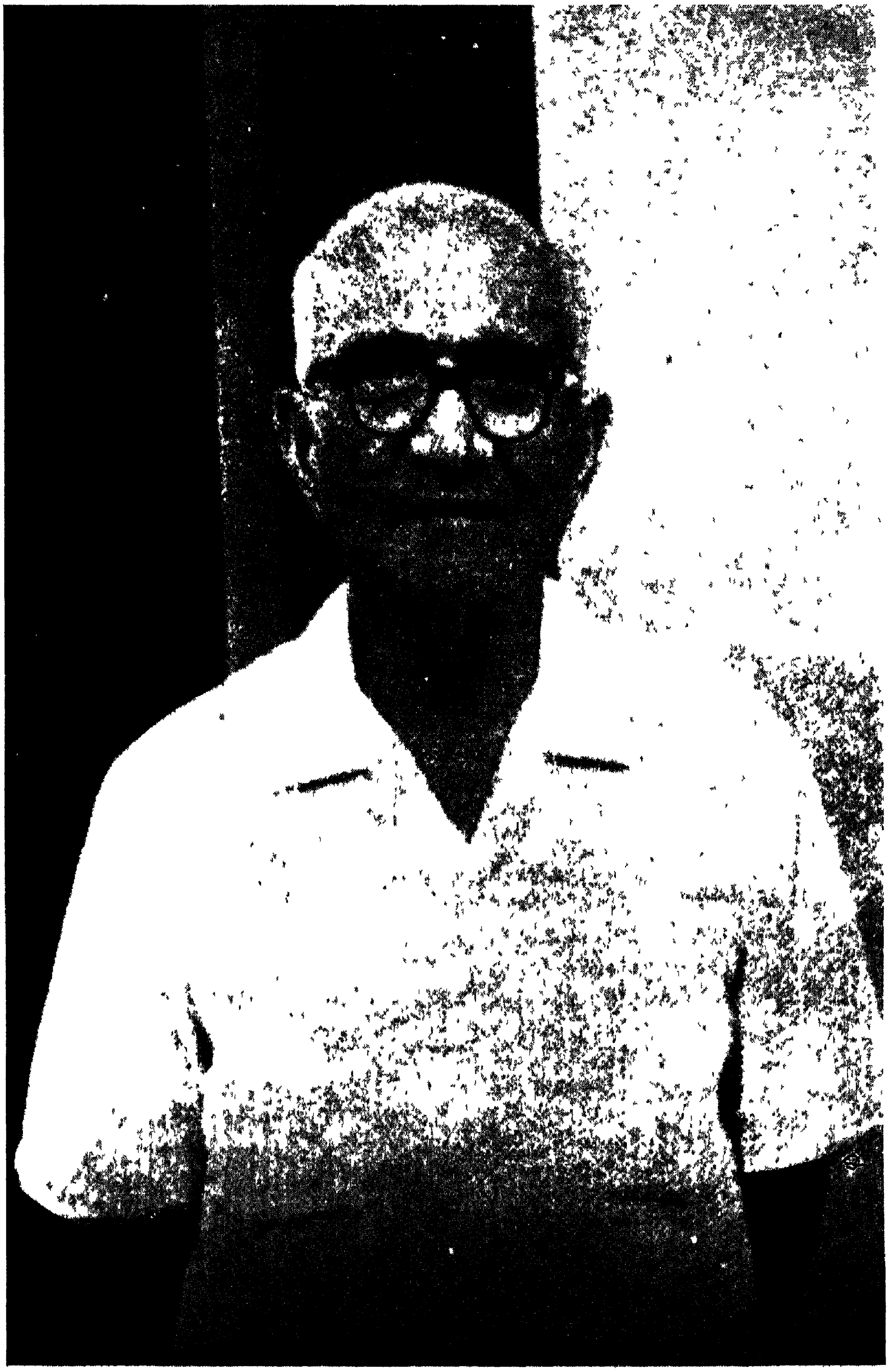
Moreover, it is through curative medicine alone that it is possible to win the confidence of the public in a country like India and bring home to the people the advantages accruing both from preventive and constructive medicine

Starting from the bottom, I consider that to meet the requirements of public health of the population there should be a combined establishment which should form the basis of preventive, curative, and constructive medicine in each village. This should be linked up with a more organized central agency discharging these combined duties and catering for a convenient sized population, the bulk of which will depend upon various factors such as communications, incidence of disease, etc. These primary organized centres will have to be supervised and assisted by a district centre in which there should be a specialized staff for the main medical subjects. These district centres in turn should be in touch with a larger provincial organization in which the staff consisting of specialists in various branches of medical science should work under a senior and experienced medical man. This latter should constitute the administrative head of the medical service in the province under the Provincial Ministry of Public Health He should have a thorough training in the methods of public health administration, community health organization, constructive medicine, etc The staff of the provincial organization should further be large enough to be utilized for medical and public health training both for under-graduate and post-graduate work

The activities of the health organization in different provinces should be co-ordinated by a more elaborate and efficient Federal or an All-India organization working under the Federal Ministry of Health The administrative head should be an officer with wide experience of preventive, curative and constructive medicine, and have on his staff expert advisers in as many of the important branches of medicine as possible With the advice and help of these advisers, it should be his duty to deal with and co-ordinate the problems of public health which concern the country as a whole Curative and preventive medicine must work as one single whole, to let them work separately in water-tight compartments is sure to lead to confusion, while only an organization of the nature detailed above will be able to deal successfully with the multifarious problems of public health in this vast country.

DR BAINI PRASHAD, FNA*

(Foundation Fellow; President, 1941-42)



Dr Baini Prashad was born on March 13, 1884 at Kirtarpur in Punjab. He received his DSc degree from University of Punjab in 1918 (First DSc of the University based on research work) and University of Edinburgh in 1927. He was the first Indian Director of Zoological Survey of India, first Fishery Department Adviser, Government of India; Member, Fishery Advisory Committee, FAO and was elected first President of FAO sponsored Indo-Pacific Fishery Council. He was the recipient of Joy Gobind Law Gold Medal of Asiatic Society of Bengal and the Order of the British Empire (OBE).

Dr Baini Prashad studied recent and fossil Vivipariidae, their distribution, evolution and paleogeography. He postulated that the evolution of the shell sculpture in the Vivipariidae had a phylogenetic origin and the various series of forms evolved on more or less parallel lines. The influence of environment on convergent evolution was stressed by him in 1930 and 1931 in his works on parallel evolution of the molluscan fauna of South-East Asia and South America. He undertook series of monographic revisions of the families such as Nuculidae, Vivipariidae etc and the genus *Corbicula*. His other publications were mainly on the remains of mammals in ancient excavations in India, on fish and fisheries and on the taxonomy of some Indian termites. He was responsible for the initiation and formation of Central Fisheries Research Institute.

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*die in 1969

ZOOGEOGRAPHY OF INDIA

B PRASHAD

(delivered at Baroda, 1942)

I have first of all to express my appreciation and thanks to the Council and the Fellows of the National Institute for the high honour they did me by electing me as the President of the Institute During the year under review I have tried, as far as possible, to carry on the traditions of my distinguished predecessors in this office, and this would not have been possible but for the whole-hearted support and co-operation of my colleagues on the Council.

Development of Scientific Research: Sir Ram Nath Chopra in his Presidential Address at Madras in January 1940 briefly discussed the organisation and development of scientific studies and research in India and suggested a scheme for a body 'which could draw up a comprehensive scheme of scientific and industrial research, mobilise all available talent in the country by allotting problems to scientists and institutes best suited for their solution, provide necessary research facilities and adequate grants, and finally deal *in extenso* with all scientific and industrial problems of the entire country'.

The abnormal conditions resulting from the war are probably responsible for very little attention having been paid to the highly important question of the development of research in pure science, but a great headway has been made in connection with industrial research.

Board of Scientific and Industrial Research: In his Address at Benares last year Sir Ram Nath referred to the establishment of a Board of Scientific and Industrial Research by the Central Government. Since its inception and more particularly during the year under review the Board of Scientific and Industrial Research has carried out very important and highly valuable work under the distinguished directorship of our Fellow Sir Shanti Swarup Bhatnagar He and his associates have initiated and developed various research schemes, several of which have already found application in industry in connection with the war, while others are likely to play a very important part in the industrial development of the country as a whole In accordance with the policy adopted for the Board the results of these researches have been made available to private industrialists in the country for the development of industry, and it is gratifying to note that as a result of these researches several industrial undertakings have been started in different parts of the country This great development is undoubtedly to be attributed to the far-seeing policy and active interest of all members of the Board, as also the team-work of the various Research Committees which have been working under its aegis. The Government of India realising the great value of the work carried out by the Board have decided to constitute it on a permanent basis With this end in view Sir Shanti Swarup Bhatnagar has been confirmed in his appointment as the Director, and the Board is to be financed from an Industrial Research Fund, which will receive grants of 10 lakhs of rupees a year for a period of five years. It will be managed by a Board of Trustees consisting of some officials, and prominent scientists and industrialists, and its main function will be the fostering of industrial development in the country. A resolution to this effect was passed by the Central Legislative Assembly at Delhi in its November session. For this highly satisfactory state of affairs the country is indebted to the untiring efforts of the Hon'ble Diwan Bahadur Sir A Ramaswami Mudaliar, Member in charge of the Department of Commerce and Labour, who is also the Chairman of the Board.

This Board brings industrial research in line with other agencies in the country dealing with special branches, such as the Indian Research Fund Association for medical research, the Imperial Council of Agricultural Research for agriculture and animal husbandry, the Indian Cotton Committee for cotton, the Indian Jute Association for jute, the Lac Cess Committee for lac, etc. The name 'Board of Scientific and Industrial Research' as applied to the Board referred to above, however, is not strictly accurate, as the major part of the activities of the Board will be directed, as has been remarked above, towards fostering industrial developments in the country.

Future Development and necessity for a National Research Council: In connection with scientific planning it has become essential in almost all civilised countries to think not of individual and sectional problems only, but of all scientific problems as they concern the country and community as a whole. These problems can roughly be grouped under two main heads: (*i*) those that concern the internal organisation of science, and (*ii*) those dealing with the relationship between all scientific work and developments in the country. The very complicated problems connected with the work and future of the workers who are employed in research on the one hand and of the multiplicity of sciences, institutes, universities and other cognate research agencies on the other have created the necessity for setting up organisations not only for organising, developing and directing their activities but safeguarding the interests of these scientific workers; these functions cannot be performed by bodies interested in one or other branch only. The phrase 'organisation of research', as that great biological philosopher, the late Professor William Morton Wheeler so aptly described, "is nonsense if we take 'research' in its abstract sense, for an abstraction, of course, is one of the things that cannot be organised. All we can mean by the term is the organisation of the actual processes of research, or investigation, and since these processes are essentially nothing but the living, functioning investigators themselves, organisation of research can mean only the organisation of the investigators." All the same, the developments in the country in regard to applied research are so rapid and the conditions under which these are taking place so abnormal, mainly owing to the stress of the war, that it will not be out of place to repeat here the note of warning from an editorial in *Nature* published in 1938: 'the research organisations of the country should be truly national and responsible to the Federal Government alone. Even in an Empire the size of India, where the resources and needs of various provinces are widely different, it would seem that centralised organisation of research is the only way of avoiding waste of money and effort. The detailed planning of research must be in the hands of those with the necessary specialised knowledge, and they must be able to act without suspicion of political or racial influence'. This, in other words, stresses the necessity for having a central co-ordinating and directing agency, and I would again very strongly urge for the consideration of the authorities the constitution of a truly representative National Research Council in India on the lines of the body which has been rendering such useful service in Great Britain ever since its constitution. Similar bodies are also doing invaluable work in Canada, South Africa, Australia, etc. As I stated on an earlier occasion, 'The functions of this Council should not only include the defining of scientific policy but it should also act as an expert advisory body for planning and co-ordinating all scientific research in the country. The planning of scientific policy and co-ordination of research should be so arranged as to preclude duplication and avoid wastage of talent and available funds, but without restricting the normal work of the universities, scientific departments and institutions, or in any way curbing individual initiative which is so essential for high class research Such an authoritative body should also be able to help in bringing about the necessary reforms in the existing system of scientific education'.

The National Institute of Sciences of India was started in 1935 in response to the keenly felt need for a body which could co-ordinate the work of all scientific societies, institutions, Government Scientific Departments and Services, and cognate agencies throughout the country. One of the main items of the programme laid down for the Institute was

> 'to act through properly constituted National Committees in which other learned academies and societies will be associated as the National Research Council of India, for undertaking such scientific work of national and international importance as the Council may be called upon to perform by the public and by Government.'

Unfortunately all efforts of the Institute for the establishment of a National Research Council for India have been unsuccessful. The need for such a body in connection with the organisation, healthy and normal development and co-ordination of scientific research in the country is, however, too patent to require any further justification, and the Institute will be failing in its duty if it does not continue to press for the constitution of such a Council at an early date

Zoogeography of India

I propose to discuss briefly the Zoogeography of India. Zoogeographic studies can be carried out along different lines in accordance with the ideals in view, but the *raison d'etre* of all such studies is the elucidation of the constitution of the fauna of any particular area, its distribution, origin and relationships.

Zoogeographical Regions: Older authorities on Zoogeography like Wallace, Huxley, Sclater, Sharp, Heilprin and others mainly considered the present-day distribution of the various groups of animals, with casual references to their geological history, and from the data thus obtained attempted to divide the surface of the earth into zoogeographical regions or realms. In fact, as Ortmann[1] remarked, 'any research in this direction is deemed incomplete that is not finished by the creation or discussion of "regions" '. This method resulted in the division of the earth's surface into a varying number of realms or regions, 21 according to Schmarda[2], 6 according to Sclater[1] and Wallace[2], 2 according to Huxley[3], 7 according to Blyth[4], 9 according to Gill[5], 3 according to Blanford[6], 4 according to Dahl[7], and various others The regions were further subdivided into subregions or provinces, but the divisions were based mainly on the distribution of mammals or birds. In spite of Wallace's assertion[8] that his slightly modified scheme of Sclater is applicable to all groups of the Animal Kingdom, there is little doubt that no one scheme can serve equally for all the groups.

Indian Area: As Blanford[9], one of our most distinguished geologists and zoogeographers, remarked, 'For the study of zoological distribution there are few, if any, regions on the earth's surface that exceed British India and its dependencies in interest. The area is large, nearly 1,800,000 square miles, and although the vertebrate fauna is by no means thoroughly explored, it is well known throughout the greater part of the area . . The variety in elevation and of climate is remarkable; the country is bounded on the north by the highest of known mountain ranges, and by the loftiest plateau on the earth's surface, and it includes within its limits both the almost rainless area of the Sind Desert, and the locality in the Khasi Hills distinguished by the heaviest rainfall known Another element of interest is the fact that the Peninsula of India is a land of great geological antiquity, there being no evidence to show that it has ever been submerged, although the greater part of the Himalayas and Burma have at times been beneath the sea.' Blanford[10] admirably defined the limits of the area as consisting 'of the dependencies of India with the addition of Ceylon, which, although British, is not under the Indian Government. Within the limit thus defined are comprised the whole of India proper and the Himalayas, the Punjab, Sind, Baluchistan, all the Kashmir territories with Gilgit, Ladak, etc., Nepal, Sikkim, Bhutan and other cis-Himalayan States, Assam, the countries between Assam and Burma, such as the Garo, Khasi and the Naga Hills and Manipur, the whole of Burma with Karenni, and of course Tenasserim and the Mergui Archipelago, and lastly the Andaman and Nicobar Islands.' With this we have also to include the Laccadive and Maldive Islands, which not only are under the Indian Government, but the fauna of which shows very distinct affinities with that of the Indian area. On the other hand Burma, which administratively is now a separate entity, must still in view of the faunistic relationships be included within the Indian area.

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[1] *Proc Amer Phil Soc*, XLI, p 271, (1902).

[2] Schmarda, K *Die Geographische Verbreitung der tiere*, (Wien, 1853).

[1] *Journ Proc Linn Soc London* (Zool) II, pp 130-145, (1858)

[2] Wallace A R *The Geographical Distribution of Animals*, Vols I, II, (London, 1876).

[3] *Proc Zool Soc London*, pp 294-319, (1868).

[4] *Nature*, III, pp 427-429, (1871).

[5] *Proc Biol Soc Washington*, II, pp 1-39, (1884).

[6] *Proc Geol Soc London*, pp 76, 77, (1890).

[7] Dahl F *Oekologische Tiergeographie*. I. pp 102-106, (1921)

[8] *Nature*, 49, 610-613, (1894).

[9] *Phil Trans. Roy Soc London*, CXCIV, p 336, (1901).

Zoogeographical Position: It will be presumptuous to claim that we are, by any means, fully acquainted with the forms of animal life which inhabit this vast subcontinent, but one would not be far wrong in saying that we are today fairly well informed about the main features, and in many cases, even the details of its fauna The limits of India, as defined above, fall mainly within the Oriental Region of Wallace or the Eastern Palaeotropical region of some authors Probably, however, as Blanford suggested, the best name for the region, owing to the earlier use of the name Oriental by the botanists for South-western Asia and Persia, is Indo-Malay, as explored by Elwes for Birds This name also is not very suitable, as practically the whole of the Western Frontier Province, the greater part of the Punjab, and the Western Himalayan area to the western limit of Nepal with Gilgit and Ladak should undoubtedly be included in the Holarctic or the Palaearctic Region rather than the Indo-Malay. Further, parts of the Indo-Gangetic Plain show closer affinities to the Western Frontier territory than to the rest of the Indo-Malayan area

Subregions of India Owing to the heterogeneous nature of the faunas of the different parts the division of this vast area into subregions is not an easy task The affinities of the faunas of the different areas are very complicated and probably the best course under the circumstances is to take physiographical rather than zoogeographical tracts as the basis for the consideration of the faunas of different parts In this connection it will be useful to consider here briefly the history of the various attempts that have been made by earlier workers for subdividing the Indian area into subregions Jordon[1] taking the Birds and Gunther, the Reptiles, as the bases for their conclusions, divided India into several subregions, but their subdivisions were based mainly on geographical units rather than on the available zoological data. Blanford[3] basing his scheme on the distribution of the Land Mollusca divided India into four Provinces which he designated: (1) the Punjab Province, (2) the Indian Province proper; (3) the Eastern Bengal Province, and (4) the Malabar Province with Southern Ceylon The Indian Province proper was subdivided into four sub-provinces Elwes[4] who considered India with Malay Peninsula as a single unit (Indo-Malay Region) for Birds, divided it into three subregions: (1) Himalayan or Himalo-Chinese; (2) Indian, and (3) Malay. Wallace[5] from a general consideration of the distribution of all the groups of animals divided the Oriental region into (1) Hindustan or the Indian subregion consisting of the whole of the Peninsula from the foot of the Himalayas on the north to somewhere near Seringapatam on the south-east and Goa on the south-west, (2) Ceylon and South India, (3) Himalayan or Indo-Chinese subregion comprising the Himalayas as far west as Kashmir from the base to an elevation of 9,000-10,000 feet, and the countries east of the Bay of Bengal, Assam, Burma, Southern China, Siam and Cochin China; and (4) Indo-Malaya or the Malayan subregion consisting of the Malaya Peninsula and the Archipelago. Kobelt[1] basing his conclusions mainly on the distribution of the Mollusca divided it into · (1) the north-western area of the Indus Plateau limited in the south-east by a boundary running almost in line with the Aravalli mountain range, (2) the greater part of the Peninsula in the south bounded by a line from Goa on the west to Madras on the east, on the north-west by the Aravalli range and including almost the greater part of the Gangetic shed—the latter bordered on the north by the Himalayan chain and on the east by a line running from the eastern border of Nepal to a little to the west of Calcutta; and (3) the Basin of the Brahmaputra including a part of Bengal, the whole of Assam and the hill areas of the Garos, Nagas, etc , and bounded on the east by a line running from Cape Negrais along the Arrakan Yomas and then running further east along the Irawadi river to Tibet He did not include Burma and Tenasserim in this account. Sharpe[2] from the distribution of the Birds divided the Indian region into. (1) Indian Peninsular subregion; (2) Indo-Malay subregion; (3) Indo-Chinese subregion; (4) Himalo-Malayan subregion, and (5) Himalo-Chinese subregion Blanford[3] in the Introduction to the Mammalia in the *Fauna of British India* divided the region into six subregions (1) Tibetan; (2) Himalayan; (3) Indian; (4) Malabar or Ceylonese, (5) Burmese, and (6) South Tenasserim Newton[4] and Gadow[5] in discussing the distribution of Birds and W L Sclater[6] of the Mammals, followed Wallace, but united his Indian and Ceylonese regions into a single unit Blanford[7] in his classical work on the Distribution of the Vertebrates of India, divided the whole area into 5 subdivisions: (1) The Indo-Gangetic Plain, (2) the Indian Peninsula; (3) Ceylon, (4) the Himalayas, and (5) Assam and Burma, and further subdivided these into 19 tracts Alcock[8] taking the freshwater Crabs as the basis for his work divided India into 6 territories: (1) The Western Frontier territory; (2) Western Himalayan territory; (3) North-Eastern Frontier or Eastern Himalayan or Eastern sub-Himalayan territory; (4) Burma-Malay territory; (5) Peninsular territory; and (6) Indo-Gangetic Plain. Annandale[9] found that the distribution of the freshwater Sponges and Polyzoa confirmed Alcock's conclusions, but it was necessary to divide the Peninsular territory into (*a*) the main area consisting of the Peninsular east of Western Ghats, and (*b*) Malabar zone including the Western Ghats from Taptee River to Cape Comorin and eastwards to the sea He also considered Ceylon as a separate territory. Stephenson[1] in discussing the Geographical Distribution of the Oligochaeta opined that in addition to the territories recognised by Annandale it was necessary to separate the narrow southern end of the Peninsula below the level of Goa and south of the fifteenth parallel from the eastern to the western shore as a distinct region. Christophers[2] for the Anopheline mosquitoes divided India into 6 areas: (1) Trans-Indus area; (2) Indo-Gangetic area; (3) Peninsular area; (4) Malabar and Ceylon; (5) Assam and Burma; and (6) Himalayan area. Taking into consideration the results of systematic work on various groups of animals I suggested the following scheme:[3] (1) Western Frontier Territory including Baluchistan, the North-Western Frontier Province and the greater part of the Punjab; (2) the Himalayas consisting of the Upper Indus Valley with Ladak, Gilgit, etc., the Western Himalayas from Hazara to the western limit of Nepal, and the Eastern Himalayas from the limit of the Western Himalayas to the Mishmi Hills above the Assam Valley; (3) Assam and Burma comprising the greater part of the Lower Brahmaputra Drainage System and the Burmese territory including Tenasserim; (4) the Gangetic Plain to the east of Delhi, and including the whole of the United Provinces, Bengal, and parts of Assam up to the base of the Assam Hills, together with the plain of the Brahmaputra as far as Goalpara and Cachar, Sylhet and the plains of Tipperah; and (5) Peninsular India, with the Malabar zone as a very distinct subdivision, and Ceylon Malcolm Smith[4] suggested the division of the Indian subregion into: (1) the Desert Area or North-West India including Baluchistan, the North-West Frontier Province, the Punjab, western Rajputana as far as the Aravalli range, and Sind; (2) Kashmir and the Western Himalayas as far east as, but not including Nepal; (3) the Gangetic Plain, extending from the valley of the Indus in Sind to the right bank of the Brahmaputra in Bengal, (4) Central India—the tract of country lying between the Gangetic Plain and the Deccan and bounded on the west by the Aravalli range and on the east by the Chota Nagpur area; (5) the Deccan, consisting of the greater part of the Peninsula of India between 12° and 21° north latitude; (6) the Mountains of the Malabar Tract and Ceylon, and (7) the Chota Nagpur Area, consisting of Bihar south of the Gangetic Plain, the northern part of Orissa and the eastern part of the Central Provinces Recently Mahendra[5] from a study of the distribution of the amphibian and reptilian species divided India into ten provinces: (1) the arid or semi-arid Province of North India; (2) the Western Himalayas; (3) the Trans-Gangetic Province; (4) Southern Burmese Province; (5) the Gangetic Plain and the adjacent country as far south as 20° latitude; (6) South India below 20 latitude excluding the Travancore Province, (7) the Travancore Province, (8) Ceylon; (9) the Andaman Islands, and (10) the Nicobar Islands.

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[10] Blanford W T *Fauna Brit Ind, Mammalia*, p iv, (1889).

[1] Jordon T C, *Birds of India*, p xxxix, (1862)

[2] Günther A C L G, *Reptiles of British India*, p vii, (1864)

[3] *Jour A Soc Bengal*, XXXIX, pt ii, p 336, (1870).

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[4] Elwes H J, *Proc Zool Soc London*, pp 652-682, (1873).

[5] Wallace A R *op cit*, 1, pp 81, 82, 321-334

[1] Kobelt W, *Ber Senckenberg naturf Gesel Frankfurt a M*, pp 89-104, (1899)

[2] *Nat Sci* III, p 108, (1893).

[3] Blandford W T, *Faun Brit Ind, Mammalia*, p iv, (1888).

[4] Newton A, *Dictionary of Birds*, p 356, (1893).

[5] Cadow H Bronn's *Klass Ord Thier, Vogel*, p 296, (1893).

[6] Sclater W L, *Geogr Journ*, VII, p 380, (1896); also see Sclater W L and Sclater P L, *The Geography of Mammals*, (1899).

[7] *Phil Trans Roy Soc London* CXCIV, pp 343-348, (1901).

[8] Alcock A W *Cat Ind Dec Crust Coll Ind Mus*, pt i. *fasc* ii, pp. 9-14, (1910).

These attempts to divide the vast area of continental India, useful as they are, have unfortunately not helped materially in unravelling completely the very complicated questions of the origin, distribution and relationships of its fauna. In what follows I propose to give a brief outline of the faunal constitution and their relationships for the different parts in accordance with my scheme referred to above.

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[9] Annandale N, *Faun Brit Ind, Freshw Sponges, Hydroids and Polyzoa*, pp 7-10

[1] Stephenson J, *Faun Brit Ind, Oligochaeta*, pp 12-13, (1923).

[2] Christophers S R *Proc Fourth Entomol Meeting*, pp 206-208, (1921).

[3] Prashad B, *The Indian Empire*, pp 190, 191, (Calcutta, 1927).

[4] Smith M A, *Faun Brit Ind, Reptiles and Amphibia*, 1, pp 18-21, (1931).

[5] *Science and Culture*, IV, pp 374, 377, (1939).

Western Frontier Territory: The fauna of the Western Frontier Territory is markedly different from that of the rest of the area. Practically all the genera of the Vertebrates are either Palaearctic (Holarctic), or are peculiar to this subregion; the relationships of the latter are also with the Palaearctic rather than with the Indo-Malayan forms. Blanford basing his views on the distribution of the Vertebrates suggested that this subregion should be classified with the Eremian or Mediterranean subregion of the Palaearctic, and this view has been fully confirmed by the distribution of the various groups of the Invertebrates that have been studied since 1901 Some forms of the Gangetic Plain have also migrated into this subregion, but they are of no importance from the zoogeographic point of view. The Western Frontier Territory consists of desert or semi-desert tracts, except near the rivers or the artificially irrigated and cultivated parts. The annual rainfall is not heavy, and the fauna on the whole is poor.

Himalayas: In the Himalayan subregion the ranges above the forest limits, a part of the Tibetan plateau and the Upper Indus Valley including Ladak, Gilgit, etc , constitute a distinct division This area is very bare, the mountains are perpetually covered with snow, and there is a very great difference in the altitudes of the mountainous ranges on the one hand, and of the intervening valleys on the other; the annual rainfall is generally low. Our information about the fauna of this part is not sufficiently detailed, but in the main it is almost entirely Palaearctic. In view of these faunistic affinities this division may later have to be included with the Western Frontier Territory. The second division consists of the forest zone of the Himalayas from near the base to an altitude between 10,000 and 14,000 feet, the uppermost limit of the forest zone. It forms a belt of varying breadth between the higher mountain ranges and the Indo-Gangetic Plain. The rainfall in this division is heavier, more so in the eastern than in the western parts, and the forests of the eastern ranges are also more extensive, richer and truly tropical A fair number of Palaearctic animals from the higher mountain ranges wander down into the forests, while a few species penetrate northwards into the rather warmer valleys from the plains in the south. The western forest region has a predominantly Palaearctic fauna, while the eastern, which has a very marked Malayan element, was on this account separated with Assam, Burma, etc , into what Blanford designated as the Trans-Gangetic subregion

Assam and Burma: In Assam and Burma the northern region, comprising the northern part of the drainage area of the Brahmaputra and Assam, consists of hilly tracts with dense forests except in the plains of Assam; the annual rainfall in this tract is fairly heavy Physiographically, parts of this area belong to the Indo-Gangetic Plain, but its fauna is distinctly Burmese In Upper Burma, which is roughly the drainage area of the Irawadi, there is a large number of hills thickly covered by forests, while the undulating ground between the mountains is densely overgrown by brushwood and high grass, the annual rainfall in this region is pretty heavy. The Tenasserim area consists of two distinct tracts, (*i*) the northern, covered by thick forests on a hilly ground and with a fauna of the Burmese type, and (*ii*) the southern area which in its physiography is similar to the northern; the annual rainfall in this tract is not so heavy as in the northern area, and its fauna is distinctly Malayan The Andaman and Nicobar Islands, which are also included in this subregion, are covered by dense forests and have a heavy rainfall. The fauna of these islands is by no means identical; the Andamans having an impoverished Burmese fauna, while that of the Nicobars is undoubtedly Malayan.

Gangetic Plain. Since the main part of the Indus Plain has been separately considered above in the Western Frontier Territory, I use the name Gangetic Plain for the rest of the Indo-Gangetic watershed Its extent has been noted already, and its physical features only need be considered Most of the western area is cleared and used for cultivation, and only some of the uncleared areas are covered by tall grasses The annual rainfall generally is not very heavy In the eastern part of the area, except for the Sunderban forests in the deltaic region of the Ganges, the country is similar to that in the north-western part, but the rainfall is heavier, and there are more extensive tracts of uncleared land The fauna of the area is generally of the same type as that of Peninsular India, but in the north-eastern parts there is a large admixture of the eastern or Blanford's Trans-Gangetic types. The freshwater fauna shows a very marked similarity and in many cases actual identity with the forms occurring in the Indus System

Peninsular India. The greater part of Peninsular India, with the exception of the Malabar Tract, consists of either cultivated land or low hilly country covered with brushwood or thin forests; the average rainfall is from 35-50 inches In the Malabar Tract, on the other hand, we have the high mountain ranges of the Western Ghats and the west coastal area of the Peninsula Most of this part is covered with thick tropical forests, though there are many places near the coast which are cleared and cultivated The island of Ceylon, like Peninsular India, consists of two types of country About three-fourths of the island along the north and the east resembles the main area of Peninsular India, and is almost plain or only slightly undulating country of no great elevation, with an average annual rainfall of about 50 inches. The rest or the south-western part of Ceylon, like the Malabar Tract, is hilly, with rich tropical forests and an average rainfall of over 100 inches.

In this area a peculiar admixture of the different faunas seems to have taken place In main characteristics the fauna of this area differs from that of Blanford's Trans-Gangetic tartly in the absence of numerous Eastern types, and partly by the presence of two other distinct constituents, which form, especially in the forests, the majority of the animal population of the area One of these constituents to which Blanford gave the appropriate name—the Aryan faunal element--consists of certain genera of mammals, birds and reptiles The typical genera of this Aryan element are, for the most part, represented in the tropics of Africa at the present day, but do not occur in Western Asia or Northern Africa. Other genera of the Aryan element found in Peninsular India occur in Western Asia and are represented at the present day by allied species Both these groups of genera are well represented in the Pliocene Siwalik Fauna of the Himalayan foothills, and it appears probable that most of them are descended from animals which appeared in India, so far as we know at present, in the Pliocene period, a few, however, may be later migrants On the whole, this Aryan element is subtropical rather than tropical, and is best developed in parts where the rainfall is moderate. Several of its most conspicuous and characteristic members, such as the Antelope and Nilgai, are not found in the extreme south of India or in Ceylon, and they are inhabitants of the grassy and bush-covered plains with scattered trees, not of dense forests and bamboo-jungle in which the gaur and the elephant flourish The second constituent of this fauna is the Indo-Malayan or the Oriental element It is more diffuse and much more richly represented in the damp tropical forests of Malabar and Ceylon than in the drier parts of the Peninsula. The diffusion of the Indo-Malayan element seems to indicate that it is older than the Aryan element mentioned already, but there can be little doubt that it is an immigrant and not an indigenous element, for it is only an impoverished representative of the typical Oriental life found in the countries to the east of the Bay of Bengal. Its main representatives are amongst birds and mammals, and like the Aryan it appears to have migrated into Peninsular India about the Miocene times driving the earlier Dravidian into high ranges of hills, etc Some authors have opined that the Oriental or the Indo-Malayan fauna, owing to the presence in it of representatives of the Lower Miocene and Oligocene faunas of Europe, is of Palaearctic origin and that it was driven down into the tropics by the diminishing temperature of the Holarctic region in the Miocene times The third element in this fauna that can be recognised distinctly from the other two is what Blanford termed Dravidian It is thoroughly tropical and damp-loving, and is only represented by lower groups of the Animal Kingdom, *viz*, reptiles and batrachians. It is probable that this is the oldest element and may have inhabited the country since India was connected in Mesozoic and early Cenozoic times with Madagascar and South Africa, across what is now the Indian Ocean.

In the fauna of the Peninsula in Malabar and Ceylon there is a much greater concentration of the Oriental element There are, for example, various mammals, reptiles, batrachians, fishes, and invertebrates, which are represented in Burma and the Malay countries but not in northern India. There is also the occurrence of certain Himalayan species on the mountains of Southern India and in Burma and even further south but not in the intervening area. These faunal anomalies have been explained as a result of the Glacial Epoch, but the explanation is not quite satisfactory, though it is hard to understand how otherwise the animals of temperate Himalayan types could have migrated to the hills of Southern India and Ceylon on the one hand, and those of Burma and the Malay Peninsula on the other After the Glacial Epoch when the country became warmer, the Oriental fauna must have migrated rapidly from the south-east into Eastern Himalayas At the present day the comparatively narrow plain of the Brahmaputra in Assam is far more extensively covered with forests than the much broader Gangetic Plain, and if, as is probable, the same differences existed at the close of the Glacial Epoch, it is easy to understand why the Trans-Gangetic fauna of Burma and the south-east had greater chances of occupying the vacant region of the Himalayas than the Cis-Gangetic fauna which had been driven much further south by the cold A reference may here be made to the Aethiopian element in the fauna of Peninsular India As was pointed out by Annandale[1], several groups of Invertebrates, Sponges, Polyzoa, Hydroids, Oligochaetes, Crustacea and Mollusca, found in the Malabar tract, show a very great affinity, if not distinct identity, with the forms found in Africa.

Palaeogeographical Considerations. Finally, reference may be made to some Palaeogeographic facts in regard to the origin of the Indian fauna The early Tertiary or placental mammals of Europe, and presumably also those of Asia north of the Circum-continental sea, the Tethys, drifted either as such or as their descendants by certain routes—of which we have only indications—into the fragments of Gondwanaland represented by Aethiopian Africa on the one hand and Peninsular India on the other Meantime, evolution went on rapidly to the north of the Tethys giving rise to the more modern and highly evolved types of mammals. About the end of Tertiary times, as a result of the receding of the Tethys, communication between the northern with the southern lands seems to have become easier, and this, combined with the climatic changes, led to a great rush south-wards of the more modern types. These overwhelmed the earlier fauna in the southern lands, driving its few representatives into the more outlying or upland areas, or wiping them out altogether off the face of the earth. In the case of the Oriental region the Central Himalayas which had meanwhile risen as the mighty mountain chain of Asia and the Tibetan plateaux to their north formed a real barrier. In the north-west, where this mountain chain is comparatively less higher and less continuous, this barrier was not so effective, but the Afro-Asian arid belt which is continued into India as the Sindh desert, formed a very efficient barrier. Through the passes in the north-west of the Himalayas the recently evolved mammals found their way into India, but naturally only forms which could withstand arid conditions or were adapted to mountain life, were able to use this route. The areas further to the east, which have been clothed for a long time with forests and are without high mountain barriers, offered greater facilities for the spread of animals adapted to wooden regions India proper may thus be conceived as having had two converging streams of immigrants, one coming from the north-west and the other from the north-east In view of the fact that the Indian Peninsula narrows southwards, it is clear that very few representatives of the Tertiary fauna in this area could successfully withstand the inroads of the more highly evolved immigrants from the north. The area to the east of the Assam neck, or the region where the Bay of Bengal pushes upwards towards the Himalayas narrowing the country into a bottle-neck shape, was, however, more favourably placed in this respect, as only a few immigrants were able to traverse the Assam neck Further, as the members of the earlier fauna were pushed south wards by the incomers into an area of almost equatorial climate, it is not difficult to surmise that survival was possible only for such forms as could adapt themselves to the highly specialised climate and surroundings. As a result this earlier element of the fauna was mainly wiped out, and at the present day is only poorly represented in the area.

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[1] Annandale N *Proc Ninth Congr Internal Zool Monaco*, pp 579-588,(1941).

Faunal Anomalies: In this account I have not considered the very interesting cases of the occurrence of identical aquatic species in the Indus and the Ganges river systems, which at the present day constitute quite distinct and unconnected systems. This has been explained on the hypothesis of a continuous river in place of the two river systems during the Tertiary times The mighty river, which has been designated the Indobrahm by Pascoe or the Siwalik River by Pilgrim, is supposed to have run from the east to the west and broken up into three river systems with the elevation of the Himalayas, resulting in similar forms being left in the different river systems[1] Similarly closely allied, if not identical, aquatic species which occur in Bengal-Assam region on the one hand and Peninsular India on the other, are to be explained on the basis of very different river systems during the Tertiary times in these areas, and the changes that occurred during recent geological times due to river captures, beheading of rivers, etc In this connection the continuity of the mountain ranges of the Chota Nagpur Plateau westwards to the Satpura range and eastwards to the Himalayas has also been suggested, and it is surmised that along this continuous chain of mountain ranges the migration of the Himalayan aquatic fauna to Peninsular India took place. Further work in connection with these problems is, however, necessary before they can be satisfactorily dealt with. Similarly the occurrence of *Typhloperipatus* in the Abor Hills of Assam, *Herpele* in Assam, *Pseudomulleria* in the Kadir Hills of Mysore and other archaic types needs a great deal more of intensive zoological work before their relationships and distribution can be properly understood.

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[1] For a detailed discussion of the present position in reference to this Tertiary river, see Prashad B *Rec Geol Surv Ind*, LXXIV, pp 555-561, (1939).

CONSERVATION OF WILD LIFE IN INDIA

B PRASHAD

(*delivered at Calcutta*, 1943)

There is very little to comment upon in the way of development of scientific research in the country to what I stated in my address last year, but attention may be directed to the fact that in view of the urgent war requirements a great deal of attention has been paid during the year to applied scientific and industrial research. Scientific research in basic sciences has generally been relegated to the background while the prevailing conditions in the country during the year made it impossible for workers and teachers being able to devote sufficient time or attention either to research or the teaching of science. Special mention may here be made of a further development in the constitution of the Board of Scientific and Industrial Research and the Industrial Utilization Committee which were established by the Government of India in 1940 for co-ordinating and generally exercising administrative control over the ever-expanding activities of these two organizations The Government of India have recently constituted a Governing Body of the following. (1) the Hon'ble Member of the Council of His Excellency the Governor-General in charge of the portfolio of Commerce (*Ex-officio*); (2) a representative of the Commerce Department of the Government of India, appointed by the Government of India; (3) a representative of the Finance Department of the Government of India, appointed by the Government of India; (4) two members of the Board of Scientific and Industrial Research elected by the said Board; (5) two members of the Industrial Research Utilization Committee elected by the said Committee; (6) the Director of Scientific and Industrial Research, and (7) one or more members to be nominated by the Government of India to represent interests not otherwise represented. The functions of the Board have been further elucidated, and it has also been decided that a fund, viz , the Industrial Research Fund, should be constituted by grants from the Central Revenues to which additions will be made from time to time as funds become available from other sources. These 'other sources' will comprise grants, if any, by Provincial Governments, by industrialists for special or general purposes, contributions from Universities or local bodies, donations or benefactions, royalties, etc., received from the development of the results of industrial research, and miscellaneous receipts. The Council of Scientific and Industrial Research will exercise full powers in regard to the expenditure to be met out of the Industrial Research Fund subject to its observing the bye-laws which will be framed by the Governing Body of the Council, from time to time, with the approval of the Governor General-in-Council For extending the work of the Board, it has been suggested that Provincial Advisory Boards of Scientific and Industrial Research should be established by the Provincial Governments to form liaison with the Central Board Welcome as these developments are, it is unfortunate that more representatives of principal scientific bodies, societies and Universities from different parts of the country have not been included either in the main Board or the Council of Scientific and Industrial Research. Our Institute has been pressing for such representation since the date when the establishment of these bodies was first contemplated,and it is hoped that authorities concerned will take steps to make good this omission at an early date. Mention may also be made of the establishment of a Utilization Branch of the Geological Survey of India; this should ensure the rapid development of the mineral resources of the country, and add fresh laurels to the brilliant achievements of the oldest scientific service in the country

It would be a truism to reiterate that we are living in times when great confusion of thought pervades almost all spheres of life As a result of scientific advances and their application to modern warfare most well-established values on which man used to base his sense of security have lost nearly all significance. Naturally under such conditions of stress and turmoil, which are influencing practically all spheres of life, doubts and fears are expressed about all plans and programmes of development, and the suggested remedies often appear contradictory and conflicting. Scientists are equally influenced by this unstable state of affairs, and there can be little doubt that if they are to serve the best interests of humanity —for that after all is the *sine qua non* of all progress, whether scientific or otherwise—they can no longer continue to develop as pure *Scarabees.* In addition to being specialists in some scientific subject they must, one and all, have a good knowledge of various social sciences, and become as conversant as possible with the pressing needs and problems of humanity as a whole Equally with this training of the scientists more attention will have to be paid to the education of the general public in matters pertaining to science and its applications These two essentials are, both of them, undoubtedly long-term projects, but if scientists are to do more than simply act in an advisory capacity dealing with special problems as they arise and without reference to their social contacts, it is undoubted that these two essentials must receive urgent consideration at the hands of the Government and the scientists themselves. Carefully considered long-term programmes must be drawn up in regard to the future of science and scientists, and in this connection it is urgent that the importance of organizing scientific effort should be fully realized. It is also essential to emphasize that the development of pure science should not be curtailed as a result of such organization, for as Professor Bernal so eloquently expressed in a recent article 'There is no reason, however, for the fear that as a result of the experience of the war the development of free science will be curtailed or stunted Effective organization of science implies neither an exclusive concern with problems of immediate application nor the subjecting of scientists to the discipline of a rigid and unimaginative bureaucracy Those who have been working for an improvement of the present chaotic system of science in the direction of using it more effectively for human welfare realize fully that any such development would immediately frustrate their ends. If applied science was exclusively followed, the basic principles on which any new development, however practical, must depend would never be elucidated '

Unfortunately, almost all developments in India within recent years have been directed towards the organization of Applied Science as opposed to Pure Science The importance of this development cannot be underrated but more attention must be paid to see that with the development of Applied Science more facilities are provided for pure scientific studies and research, and it is in this connection that the National Institute of Sciences can render invaluable service to the country. Pure Science also requires not only increased endowments but more equipment, for as Professor Armstrong has rightly summed up. 'Good workshops and good teachers mean able students and first class research. a steady flow to a progressive industry.' Let us hope that this point of view will not be lost sight of by the authorities in this country and that as soon as conditions permit, efforts will be made by our Institute to have better facilities provided for the development of Pure Science equally with those provided for applied scientific work.

Conservation of Wild Life in India

Compared with other living creatures man is relatively a new-comer on the face of the earth. Even according to most liberal estimates primitive man did not appear till about a million years ago. In this relatively short period he has developed from a very primitive creature to a highly evolved dominant personality on the face of the earth Man in the course of this period passed through various stages of development which, according to the material used by him for his tools, are respectively named the Stone Age, the Bronze Age and the Iron Age In very early stages he began by shaping tools from bits of stone or bone, and it was only later that through gradual and hard experience he learnt to work metals which have played such an important role in the evolution and development of the present-day civilization. During this period of earth's history man has very materially influenced the plant and animal worlds, and his relationships with both these have become extra-ordinarily varied and intricate. In the earlier stages man's relations with at least the larger animals were those of direct competition in a very keen struggle for existence The animals supplied the major part of his food and primitive clothing and various other products that he required for his very simple way of life Later, however, when he assumed greater mastery over the surroundings in which he lived, he, in addition to agriculture, took to domesticating certain classes of animals for making them his help-mates and companions. Several of them, such as the cattle and the horse, not only proved invaluable in connection with the advance of civilization but gradually made it possible for man to occupy the proud position which he holds on the face of the earth today. *Inter alia* it may be noted that authorities are at variance in regard to the exact sequence of the agricultural and animal husbandry activities of early man. Modern man through horticulture and animal husbandry has developed numerous varieties of cultivated plants and domesticated animals which have made available a very large range of food materials for his use With the advance of civilization has also been perfected a very complex and rapid system of communication and transportation, and this renders it possible for man to enjoy not only the seasonal products of one area, but of almost all parts of the world In fact, as a result of these developments animal and plant products from different areas are, in normal times, easily distributed all over the globe.

No substitutes for plant and animal products, which are so essential for human existence, have so far been discovered and in spite of all scientific advances, man is still and will remain dependent on plant and animal worlds for his continued existence. In both international and national interests, therefore, it is of the utmost importance that carefully considered long-range programmes for the conservation of wild life be adopted all over the world

In earlier times extensive areas of undisturbed forests and uninhabited parts in almost all countries provided safe sanctuaries where wild life was able to survive and even flourish, but changed conditions as a result of the rapid advance of civilization and over-population, the gradual conquest of forests and grasslands, the opening up of new roads and waterways, and highly improved methods of transport have today left very few areas where wild life can continue to live undisturbed by man. These factors have had and are continuing to have a very devastating effect on wild life. With these developments fortunately a gradual change is taking place in man's outlook towards Nature. This change is due to the spread of education, and the realization of man's dependence on natural resources. Apart from humanitarian measures, authorities are gradually becoming alive to the inherent dangers underlying the uncontrolled destruction of wild life. This movement for the protection of Nature and so of wild life had its origin barely 50 years back. Though the European nations paid a fair amount of attention to this highly important question, it was the Americans who led the field and set an example as to what could and ought to be done for the preservation of wild life. In the United States of America particularly the occupation and development of vast outlying stretches of the country, the extensive spread of agriculture and consequent disappearance of forests and grass-lands, the drainage of lakes and marshy areas, and the ever-increasing demands of industry have been responsible for a very great reduction in wild life, both of plants and animals. The tragedy was fortunately foreseen fairly early and has been averted, though only to a very limited extent, by the establishment of extensive National Parks or Reserves which, it was hoped, would provide inviolable sanctuaries for and preserve wild life. Such sanctuaries, originally established in the United States of America, have since been set apart in Canada, New Zealand, Australia and the Union of South Africa. In the Kruger National Park, which was founded in 1898 as the Sabi Game Reserve and changed into the Kruger National Park in 1926, South Africa has one of the most extensive and well-managed sanctuaries Mention may also be made of 'Parc National Albert' in Belgian Congo, which was created by a Royal Decree in 1925 and greatly enlarged in 1929, in 1934 by a Royal Decree its functions were greatly extended and entrusted for management to the Institute for the National Parks of the Belgian Congo which was established with its headquarters at Brussels. This National Park was due to the incessant efforts of the great naturalist, Carl Akeley, an American nature-lover who devoted all his energies to its establishment. In addition to preserving the rapidly dwindling fauna of the area, this park has saved from almost certain extinction the Gorilla, which next to man is the King of Primates. Protection of Nature movement in Germany and adjacent countries proved very valuable in connection with the conservation of wild life in the areas concerned, and extensive National Parks were established in Switzerland, Germany, Italy, Sweden, Spain, Holland and Czechoslovakia The cause of conservation was further advanced by various International Conferences. In 1900 the British Government convened an International Conference in London for the preservation of animals, birds and fish in Africa The convention was signed by seven powers interested in Africa, and was to remain in force for 15 years. In 1913 an International Conference for the Protection of Nature was held in Berne at which 17 Governments were represented. The main result of the work of this conference was to establish a central organization for dealing with the question of wild life preservation on an international basis. The world war of 1914-18 unfortunately greatly delayed the adoption of the recommendations of the Berne conference.

In 1903 a society for the protection of the fauna of the empire was founded in England by Mr E N Buxton 'with the object of awakening public interest in the assemblages of wild fauna still surviving in every part of the British Empire, and taking such steps as may be possible to save them from extinction, further to cooperate with kindred societies in the Dominions and Colonies or in foreign countries with regard to any conjoint efforts'. After the world war of 1914-18 greater attention was directed towards the preservation of fauna in most parts of the world, for as was so well expressed by the president of the society, the Rt Hon Earl of Onslow, 'The whole world is becoming so speedily opened up to travellers, traders, tourists and settlers, and so much uncultivated land is coming under the plough that unless some more or less drastic measures are taken to preserve the distinctive fauna it must obviously disappear entirely'. The society started active work for the preservation of the fauna of the empire soon after the world war, and its revised rules, which were passed on April 27, 1928, were brought into force from 1st of May, 1928. Since this date the society began to wield a great deal of influence in connection with the preservation of the fauna of the empire. Reference may also be made here to the American Society for International Wild Life Protection and the Dutch Society, for the International Wild Life Protection, which have done a great deal to further the cause of conservation of wild life in their respective spheres In 1931 at the instance of the French Government an important International Conference for the Protection of Nature was arranged by the staff of the Natural History Museum of Paris. Representatives of Belgium, Czechoslovakia, Germany, Great Britain, Holland, Italy, Latvia, Norway, Poland, Rumania, Spain and the United States of America attended the conference, and very useful spade work was carried out for the formation of a central official international organization for the protection of wild life An International Conference for the protection of the fauna and flora of Africa was convened in London in 1933. As a result of its deliberations it drafted a convention for the better preservation of the fauna of this continent Among the measures suggested were the establishment of sanctuaries, National Parks, Strict National Reserves and other Reserves The conference recommended that all settlements in National Parks should be controlled so as to ensure that as little disturbance as possible is occasioned to the natural fauna and flora It also recommended that special steps should be taken to restrict the export and import of trophies, to stop the use of motor vehicles or aircraft for the purpose of hunting, killing or capturing or driving away, stampeding or disturbing animals, and finally the use of poisons or explosives or poisonous weapons or the use of nets, pits or enclosures, bins, traps or snares, or of set guns and missiles containing explosives for hunting animals should be prohibited. Mr E C Stuart Baker, who is a recognized authority on Indian birds and wild life, attended this conference as one of the observers on behalf of India. In a report, which he submitted to the India Office, he concluded that the results embodied in the report of this conference provided a valuable basis for any measures that may be under consideration for the preservation of indigenous flora and fauna of India. With a view to deciding whether it was desirable for the Government of India to become a contracting party to the convention, either in whole or in part, he suggested that the report should be considered by the Government of India at a special conference of representatives of the Government of India, the Provincial Governments, the Indian States and the adjoining territories of Nepal, Bhutan, etc About the same time the Society for the Preservation of the Fauna of the Empire in London addressed a letter to the India Office directing attention to the urgent necessity for the protection of wild life in India With the letter it supplied memoranda dealing with the position of indigenous game in some of the provinces and offered to supply expert advice in case the Government of India decided to arrange for a conference on the subject. Meanwhile the Bombay Natural History Society, which ever since its foundation in 1883, has by intensive propaganda and through the medium of its *Journal* and various publications been rendering very useful service in creating and stimulating interest in the wild life of the country, started publishing in 1934 a series of beautifully illustrated articles on the wild animals of the Indian Empire and the problem of their preservation. This series of articles provided a detailed account of the distribution of mammals in the country together with illustrations of the more important mammals, and the condition of game in different parts of the country including Burma. The articles were written by authorities with intimate first-hand knowledge of the problems of the different areas, and as a result it was possible for the authors to indicate exactly the measures that should be taken for the protection of wild life in the different parts, as also of how these measures could be best given effect to. The Government of India also had been alive to the urgency of the situation and at their instance detailed enquiries in connection with the protection of game were being carried out all over the country. After the preliminary enquiries were completed, the Government of India convened an All-India Conference for the Preservation of Wild Life at Delhi in January 1935 with a view to reviewing the position of the fauna and flora as it existed at the time and considering generally the protection of the animals peculiar to India. The conference adopted a set of resolutions and prepared two lists of species, first of animals that were to be protected as completely as possible, and second of those which 'while not requiring such rigorous protection', shall not be hunted, killed or captured except under license granted by competent authorities. The conference laid special stress on the establishment of wild life sanctuaries, and desired the contracting parties to explore the possibilities of establishing sanctuaries in which hunting, shooting, killing or capturing of all animals was to be prohibited except under the control of the authorities responsible for the management of the sanctuaries. It was agreed by the conference that the duty of preserving the fauna should be assigned to the forest departments in the areas under their charge, but at the same time urged the necessity of co-operation of police and magistracy in carrying out the necessary measures of protection. Resolutions were also passed for the closest co-operation between the forest departments and Associations that may have been or are established with a view to the preservation of game and wild life. It also laid stress on the introduction of nature study in the country and for carrying out such propaganda as would popularize with the general public the urgent necessity of preserving wild life, as without public support no efforts to preserve wild life would be really effective. It, therefore, recommended that societies for the protection of wild life in the country should make propaganda a principal part of their work. This was further stressed by the chairman of the conference, the late Sir Fazl-i-Hussain, the Hon'ble Member in charge of the Department of Education, Health and Lands of the Government of India, in his closing remarks 'Even at this stage, I would repeat one point and that is you should not expect much from the Provincial Governments or legislatures, but if you do propaganda in the right direction in the provinces where the power will rest, you will achieve your object.' As a result of the deliberations of this conference an All-India Convention for the preservation of fauna of India was drafted. It was hoped that the convention would be adhered to by all Provincial Governments and the States, and that the signatories of the convention would adopt all possible measures for the protection of the wild life in the areas under their jurisdiction.

Here it would be useful to include a short summary of the legislative measures which were in force for the protection of wild life in British India prior to the date of the All-India Conference for the Preservation of Wild Life. These measures consisted of (1) Wild Birds and Animals Protection Act of 1912, and (2) the Indian arms Act—both of which were applicable to the whole of British India, (3) the Provincial Game Rules under the Act of 1912; (4) Provincial Forest Act and Rules thereunder, and (5) Provincial Acts dealing with protection. The Provincial Game Rules and Forest Acts had unfortunately been drawn up rather haphazardly and were often contradictory. In addition, no definite authorities had been set apart for enforcing these legislative measures particularly in regard to the poaching and the indiscriminate destruction of game, etc. There was no control of trade in meat, hides, skins and trophies, and at the same time there was no provision for the restriction of the modern methods of traffic such as motor cars and aeroplanes which were proving disastrous to wild life all over the world. Cases of shooting animals from motor cars after they became exhausted as a result of long chase had been reported. A more up-to-date and comprehensive measure was enacted in the Punjab Wild Birds and Wild Animals Protection Act of 1933, while the rules made thereunder provided for the better protection and preservation of certain wild animals including birds and fish. It later resulted in the appointment of a Game Warden for seeing that the rules were strictly enforced and the protective measures were as comprehensive as possible In addition, under the rules, District Fauna Committees were to be established in all districts for performing functions assigned to them under the rules and for advising generally about the protection of the fauna in their respective districts Acts on similar lines were also passed in the Central Provinces in 1934 and the United Provinces in 1935, while measures were under consideration in other provinces. Mention may also be made here of the Bengal Rhinoceros Preservation Act of 1932, which prohibited the killing, injuring or capturing of wild rhinoceros in Bengal Under the Act every wild rhinoceros killed or captured otherwise than by permission was to be the property of the Local Government and stiff penalties were provided against contravention of the Act A small sanctuary for the preservation of rhinoceros in Bengal was also established in Jalpaiguri district In 1934 a very great advance was made in the United Provinces through the great personal interest taken by the enlightened Governor of the Province, Sir Malcolm Hailey (now Lord Hailey), as a result of which the National Parks Act of 1934 was passed. This Act provided for the establishment of National Parks and for the preservation of wild animal life or other objects of scientific interest and for incidental matters provided therein. As a result the Hailey Park was demarcated as a National Park in the famous Patli Doon and the hill forests to the south of it consisting roughly of an area of 99 07 square miles. Under the Act the word 'animal' was defined as 'mammals, reptiles or birds', and it was an offence to kill, injure or disturb any animals or to take or destroy any eggs or nests of any birds in the park. The conditions under which the people were allowed to enter or reside in the park were laid down in the Act and were to be enforced by the forest department In Assam certain areas had already been demarcated as game sanctuaries and more stringent action was being taken to preserve wild life which according to some reports had been reduced by almost 75% within recent years. Reference may also be made here to the Chamrajanagar Sanctuary of the Mysore State Forests which had been established with a view to offering complete immunity for animals and thereby making it possible for them to thrive without interference. Introduction of other animals not found in the area was to be attempted, and the sanctuary was to provide facilities for the scientific study of the life-histories of different indigenous species of game

Mention may also be made of the valuable work which the Association for the Preservation of game in the United Provinces has been carrying on ever since its foundation After the All-India Conference for the Preservation of Wild Life this Association extended its sphere of work to the whole of India, and in July 1936 started publishing a journal entitled *The Indian Wild Life* Its aims and objects are very comprehensive, and the two Honorary Secretaries, Major J Corbett and Mr Hasan Abid Jafry, have been carrying on valuable work in connection with the protection of wild life throughout British India and in most of the Native States as well. Unfortunately, owing to the abnormal conditions resulting from the war, the membership of the Association has fallen off and it has had to stop publication of its journal, but it is to be hoped that this is a temporary setback, and before long it will be possible for the Association to restart publication of its journal and carry on its activities on a more extensive scale.

From the above it will be seen that a

certain amount of spade work had been done and various provinces were becoming alive to the urgency of adopting measures for the protection of wild life in the areas under their control. Unfortunately, however, only one aspect of the conservation of wild life had been considered in all these plans, *viz*, that of the protection of game mainly from the point of view of sport Further, in all the measures suggested and partially adopted the work, except in the Punjab, was to be carried out by agencies which were already overburdened with work, and naturally the task of looking after wild life was something which it was not possible for them to carry out efficiently in addition to their normal work.

The problem of wild life conservation is not, however, so simple as would appear from the measures which have been taken in this country so far. In fact the multiplicity of the problems involved in any scheme of wild life conservation has begun to be realized only within very recent years. The greatest advances in this connection have again been made in the United States of America, where under the President's Reorganization Plan No III a Bureau of Biological Survey was constituted on June 30, 1940, by the consolidation of the Bureau of Biological Survey and the Bureau of Fisheries, this Bureau is responsible for the conservation of wild life in the extensive continental area of the United States of America.

It is not possible to give in this address a detailed analysis of all the factors which must be considered in detail in connection with any scheme of wild life conservation, but it is essential to point out that, if wild life conservation is to be a success, the conservation of soil, waterways, forests and grass-lands must receive simultaneous attention. The disastrous effects of man's activities on soil and water resources, whether direct or indirect, conscious or unconscious, are very serious indeed. As an example of direct and conscious influence of man on waterways may be mentioned the pollution of rivers, streams, lakes, etc. through the dumping of huge quantities of refuse and sewage of large cities, as also of the untreated raw wastes of large industrial concerns. Such pollution materially affects plant and animal life of these waters, and has been known in many cases to have destroyed extensive and valuable fisheries. Indirect and unconscious destruction of soil for agricultural developments has similarly done a great deal of harm. In this connection it is unfortunately seldom realized that most schemes of development of large tracts of country, whether as living centres or as agricultural land, unless carefully planned, often have very serious repercussions on the plant and animal life of the area. Nature works in a vicious circle and the interdependence of all these factors is now fully recognized by all authorities It would suffice, therefore, to point out that uncontrolled deforestation or the utilization of grass-lands for agriculture and other purposes results in a great erosion of the soil and reduction of rainfall Rivers, streams and other waterways become silted resulting in the flooding of adjacent areas, and water conservation becomes a very pressing question With the fall of waterlevel the country in general becomes dry and barren The land becomes almost useless for agriculture and does not produce even enough of grass or fodder The repercussions of all these on the wild life in the area are equally serious, as with the disappearance of grass-lands and forests very few sanctuaries are left for wild life.

To undo even a small amount of the damage to organic resources which has resulted from the rapid spread of civilization would require carefully planned long-term programmes of reconstruction, and the development of new social concepts in regard to colonization, agriculture, irrigation, forestry and other allied activities of man. In its broadest sense, conservation of organic resources, as has been so well summed up by I N Gabrielson, the Director of the Fish and Wild Life Service of the United States Department of the

Interior, 'means restoring to the highest possible level and maintaining in a state of high productivity those resources, including wild life, that can be used on a crop basis to sustain human society'. It will be clear, therefore, that in connection with any scheme for wild life conservation measures must also be adopted for ensuring that soil, water resources, forests and grass-lands are equally conserved

In wild life management the existence and operation of ecological communities in the domain of nature and man's relationships to them have to be recognized and also the fundamental fact that man's activities often have been and are responsible for disturbing ecological communities For all schemes of wild life conservation it is essential, therefore, to attempt to restore natural balance which has been and is being disturbed by human activities With increased occupation of outlying countries resulting in deforestation and disappearance of grass-lands, soil erosion becomes a material menace, rainfall decreases and the problem of water conservation becomes more and more acute Land gradually becomes impoverished and is not capable of producing enough for the human beings in the area, much less of providing food and shelter for wild life In all recent schemes of wild life management, therefore, the questions of soil erosion and programmes of re-forestation and increasing grass-land areas are considered as important as the direct measures for the protection and conservation of wild life. With the information at present available most conservation programmes must of necessity be of an experimental nature They should deal with a few species in restricted areas so that the results could be properly watched and tabulated. Only such work will gradually enable us to acquire the much-needed data and technical knowledge for evolving proper schemes of general ecological management. Meanwhile wild life management must be planned on the ecological and biological data that are at present available. In the large area of the sub-continent of India the problems of wild life conservation are bound to be very complex, but as soon as possible a programme of conservation must be formulated which would deal not only with the necessity of preserving a few species of game but the conservation of animal and plant life in general

Recently the Hon'ble Sir Jogendra Singh, Member for Education, Health and Lands of the Government of India, in his address to the meeting of the Board of Forestry rightly stressed the responsibilities of the forest officers in regard to tree plantations in villages He remarked that.

> 'The need of 7,000,000 villages in the matter of tree plantation has so far received scant attention. It may be useful to take a group of villages and start plantations Land should be rented for the purpose and trees planted to provide fuel and timber and grass for feeding the cattle These village plantations may prove of great economic value, saving the cow dung for manure, and may even provide large quantities of material for making humus and manure.'

Indicating another direction in which he felt forest officers could do useful work, Sir Jogendra Singh referred to the vast areas which owing to climatic conditions cannot be cultivated He suggested that·

> 'It might be possible to lift water for irrigation for starting plantations and to grow trees which require a minimum amount of water An experiment in this direction may enable the afforestation of the areas which now lie waste, and are classed as culturable but cannot be cultivated.'

Such a scheme would not only result in extending the greatly dwindling forests but also provide grazing area for the cattle and wild herbivores, besides affording much-needed sanctuaries for wild life In addition, the result of such a scheme of afforestation is sure to help in checking soil erosion and indirectly assist in water conservation through consequent increase in rainfall.

It is essential that similar schemes should be initiated in connection with irrigation plans which, while increasing the area of irrigated lands in the country, have materially influenced the plant and animal life of the streams, rivers, etc. The problems of water conservation in the country are in fact as important as those of the afforestation and conservation of grass-lands, and if these problems are properly tackled, they are sure to go a long way towards the solution of the problems of wild life conservation. Finally, the authorities responsible should see that the recommendations of the Wild Life Conference of 1935 are implemented and carried out as far as possible. Though various provinces are more or less autonomous in regard to the management of the areas under their charge, it should be remembered that wild life conservation in the country cannot be carried out on a provincial basis. The multifarious problems involved cannot be tackled properly until the all-India nature of the problem is realized and a separate department of the Central Government made responsible for this work While leaving the local problems to various Provincial Governments and Native States, a central department should be responsible for dealing with the policy of conservation of wild life for India as a whole.

I am afraid, I have given a more or less disjointed picture of a very vast problem I have tried to indicate that protection of game alone though urgently called for is not enough, and that steps should be taken to draw up and adopt a long-term scheme of wild life conservation as a whole on an all-India basis Until this is done it will not be possible to preserve and conserve the greatly impoverished wild life on the country.

SIR JNAN CHANDRA GHOSH, FNA*

(Foundation Fellow; President 1943-44)

Professor JC Ghosh was born at Purulia, West Bengal on September 4, 1893. He received his PhD degree from University of Calcutta specializing in electrochemistry. Professor Ghosh was the Professor and Head, Department of Chemistry, University of Dacca (1921-39), Director, Indian Institute of Science (as a successor to Professor CV Raman); Director General, Industries and Supplies, Govt. of India, first Director, Indian Institute of Technology, Kharagpur, the Vice-Chancellor, University of Calcutta and Member of the Planning Commission He was an active member of All India Council of Technical Education and President of Principals of Technical Institutions in India. He was the General President, Indian Science Congress (1939).

Professor Ghosh was the person who placed the theory of strong electrolytes on a permanent footing. The concept of electrostatic forces between ions came to be universally accepted He is also known for his work on Photochemistry, Fermentation Technology, High Pressure and Industrial Gas Reactions He will always be remembered for his role in the promotion of Education and Science and Technology in the country.

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*died in 1958

ANNUAL ADDRESS

J C Ghosh

(delivered at Delhi, 1943)

I am thankful to the Fellows of the National Institute of Sciences for the great honour which they have done me by electing me their President for the session. This is a time for great decisions and I feel weighed down by a heavy sense of responsibility. I must also confess that due to difficulties of travel in these days from Bangalore to Calcutta, I have not been able to take as active a part in the administration of the affairs of the Institute as your past Presidents have done. You have established the convention that a President remains in office for two years. It is a good convention if the President is resident in headquarters. It may become a good convention after the war, when a night's flying will bring the President from any part of India to headquarters But until that day comes, it is worthwhile considering if a President who does not reside in headquarters should remain in office for more than a year

I have much pleasure in welcoming today several distinguished visitors from overseas. Prof Hill holds a position of the highest eminence in the field of science, as secretary of the Royal Society, and a member of Parliament who has taken keen interest in the application of science to the problems of war and peace, he is particularly fitted to give us valuable advice in our deliberations today He has brought with him the following message from the President of the Royal Society which I wish to read out to you:—

> 'I am asking Professor Hill to transmit, through you, Mr President, the cordial greetings and friendly sentiments of the Fellows of the Royal Society of London to the Fellows of the National Institute of Sciences of India. We have the confident hope that one of the results of Professor Hill's visit will be to strengthen the bonds of understanding and true comradeship between our Indian colleagues and the men of science of this country.'

I wish to assure Prof Hill on your behalf that we deeply appreciate the cordiality of this message and warmly reciprocate the feelings expressed therein.

I am glad that Professor Bernal is here with us today. I am told that his fresh mind working in the new field of scientific warfare has achieved wonderful results He will be interested to know that most men of science in India work and live in the hope that the common man of this land will soon come to his own; and this symposium on Post-war Organisation of Scientific Research in India is inspired by the hope that modern developments in science and technology, if utilised to their fullest extent, can give him a fuller and more satisfying life. I also extend cordial welcome to Dr Zuckermann and other overseas visitors who have accepted our invitation to attend this function A country is great where the hour finds the man--a capable man at each post of duty, and in her hour of need, England did not find her men of science wanting May their example be an inspiration to us!

Ten years ago, the Indian Science Congress Association appointed a Committee to devise a scheme of a Central Organisation which will effect co-ordination between scientific academies, societies, institutions, Government scientific departments and services. As a result of their devoted and painstaking work, the National Institute of Sciences of India was founded in 1935 with a Council consisting of a President, six Vice-Presidents, two Secretaries, a Foreign Secretary, a Treasurer and 22 ordinary members of Council. Of the six Vice-Presidents, four are nominated—one each by the Indian Academy of Sciences, the National Academy of Sciences, the Royal Asiatic Society of Bengal and the

Indian Science Congress Association Of the 22 ordinary members of the Council, four are nominated in the same manner as the Vice-Presidents.

This constitution of the Council is designed to ensure that the relationship of the Science Academies and the learned societies in India to the National Institute is of co-operation between independent bodies In no case has it been suggested that our relationship is one of subordination or affiliation like that existing between the French Academies and the Institute of France. Our aim has always been to provide a reservoir of knowledge and experience available for application to the study of all scientific problems connected with the general welfare of the country. We have in the past tried partially to achieve this aim by regularly holding symposia on problems of wide scientific interest But no serious attempt has been made until recently to implement objective 2(*d*) in the Articles of our Association which reads as follows —

> 'To act through properly constituted National Committees, in which other learned Academies and Societies will be associated, as the National Research Council of India, for undertaking such scientific work of national and international importance as the Council may be called upon to perform by the public and by Government '

Men of science in India have rendered whatever service they could with their limited resources in aid of war-effort when called upon to do so. They felt, however, that they could have rendered more effective service if a National Research Council were in existence In England the War Cabinet is helped by a Scientific Advisory Committee which has been set up under the Lord President of the Council, and a magnificent machinery of scientific research and development have been created both for offence and defence and for maintaining a stable base of health and welfare at home. In a broadcast from Delhi on the 5th December last, Professor Hill observed 'that the history of the present war has taught us that to neglect research is to invite calamity The Battle of Britain depended on the courage and skill of a few brave young men in Hurricanes and Spitfires—but it depended also on the knowledge and skill of a few scientists sitting behind cathode ray tubes The Battle of the Atlantic has depended on the courage and skill of sailors and airmen, but it has depended also on the scientists and engineers who devised and used the means of intercepting the U-boats and confounding their devices The fact that, in spite of our hardships, the health and good humour of the people in Britain are at least as high as in ordinary times, has depended on vigorous administrative action based on knowledge of nutrition, health and even applied psychology'

In his recent Pilgrim Trust Lecture to the Royal Society, President K T Compton of the Massachusetts Institute of Technology has described the war-time scientific organisation of the United States of America First they created the National Roster of Scientific and Specialised Personnel. Do you wish to know the name of all Americans who possess a knowledge of epidemiology and chemotherapy, who are competent in the diagnosis and control of protozoal and bacterial infections, have a knowledge of the Hindusthani language and have travelled in the tropics? To secure this information, the stops of the punch-card sorting mechanism are pushed in at the appropriate places, the cards are ground through the machine, and all those who conform to the above specifications fall out together. Next they established the office of Scientific Research and Development with Dr Bush, President of the Carnegie Institute of Washington, as Director This office places annual contracts of the order of 100 million dollars with about 100 research institutions and 200 industrial laboratories and engages 6,000 scientists and engineers for the execution of these contracts. Then they have the National Defence Research Committee, Joint Committee on New Weapons and Equipment, the National Inventors' Council and, finally, the office of Production Research and Development of the War Production Board. In countries like Great Britain and the USA, which lead the scientific-cum-industrial procession of the present era, the need for mobilising scientific talent to the fullest extent is considered imperative. How much more should it be so in India where only a promising start has been made in the path of scientific exploration! Sir A Ramaswamy Mudaliar at Bangalore the other day noted with satisfaction that the Board of Scientific and Industrial Research had done excellent work in this direction, and it is also very encouraging to learn that H E the Commander-in-Chief and his advisers are keenly interested in the scientific work that is in progress in the Delhi laboratories of the Board. But one cannot help feeling that much more could have been done to enlist the scientific talent of this country in aid of war-effort.

Men of science, by training and instinct, are averse to wasting their breath over might-have-beens; it is the present and future that interest them more than the past Now that the Victory of the United Nations is in sight, planning for peace has become as important as toiling for war. In the progressive countries of the world, organisation of scientific research is considered a vital element of post-war reconstruction, and such research is being planned with a crusading zeal We have, however, not yet had any definite evidence that those who control the destiny of India share this view. If past history is any guide, we have every reason to be extremely alert Under the stress of the last Great War, the Government of India addressed the Secretary of State as follows: 'After the war, India will consider herself entitled to demand the utmost help which the Government can afford to enable her to take her proper place as a manufacturing country'. It was hoped that in accordance with the spirit of this declaration, scientific and technical research so essential for the promotion of industries would receive a great impetus. But such hopes were nipped in the bud by the Inchcape Retrenchment Committee. While in Great Britain, far-reaching steps were being taken to promote scientific and technical research by the establishment of Research Associations in co-operaion with industrial interests, and new scientific laboratories under the Department of Scientific and Industrial Research and institutions of University rank were being planned, built and equipped on a vaster scale, the Government of India, in the decade following the war, attached little importance to scientific research as an agency for human betterment. Heads of the central scientific services found to their dismay that any suggestion for maintenance of *status quo* or for modest legitimate expansion was invariably ignored if based on claims of research Some of the existing research institutes were expected to be self-supporting; and I am told that this recommendation of the Inchcape Committee was given effect to in the case of the Imperial Veterinary Research Institute at Mukteswar which was required to balance its budget by the sale of biological products The Government of India, which is ultimately responsible for the management of the Indian Institute of Science, appointed a committee in 1921, with Sir William Pope as chairman and Sir Asutosh Mookerjee as a member, to report on the future lines of development of the Institute The committee recommended the addition of eight new departments to the Institute at a capital cost of twenty-five lakhs of rupees and an additional annual recurring expenditure of five lakhs of rupees. No attempt whatsoever was made to implement the recommendations of this authoritative Committee and the annual grant to the institute remained stationary in the interwar period, 1920-1939.

Lord Reading is reported to have said that when he was the Viceroy, he sometimes had the idea of intensive planning for better living on a big scale, but he was too busy in day-to-day administration to get down to it; and he doubted if any Viceroy would find the time. It is no wonder, therefore, that when the great depression came in 1930, the Government of India had no plan but severe retrenchment to meet the situation. In America, public opinion is so thoroughly convinced of the benefits of research in industry and national life that, during the great depression, research budget was practically untouched—and in some cases the last to be cut, and in 1940, the year before the USA entered the war, the annual expenditure for research amounted to 300 million dollars In India, on the other hand, the research departments were the first to suffer and suffer grievously Thus the Geological Survey of India, which is the pivot on which every planning for industrial progress must rest, lost a third of its strength. The Geodetic and Trigonometrical Survey of India lost half its strength The Zoological Survey of India fared likewise In a country where heavy mortality has been the black spot of the administration, the annual grant of Rs 5,00,000 for medical research to the Indian Research Fund Association was discontinued. There was one silver-lining however, due to the personal interest of the ex-Viceroy, the Imperial Council of Agricultural Research was established and continued its beneficient activities with adequate financial support from the State.

In the circumstances, the Council of the National Institute of Sciences felt that the time had come when the scientific men of India should gather together and formulate a plan for post-war organisation of scientific research in India. Accordingly, they arranged a symposium on that subject which was held in Calcutta on the 27th and 28th September last. We are thankful to the Hon'ble Sir Azizul Haque for having taken a keen interest in this symposium and opening the proceedings with a sympathetic and encouraging speech.

The following tentative proposals were adopted:

I. The Council of the National Institute of Sciences of India be authorised to take necessary steps for the organisation of a National Research Council constituted under the statutory authority of the Government of India. The National Research Council shall be directly responsible to the Government and have the following functions:

(*a*) To plan the main lines of scientific work in accordance with national needs, to formulate schemes for the above purpose, to review and modify the same whenever necessary and to recommend ways and means for implementing the results of accomplished researches

(*b*) To ensure balanced development of all branches of science, and minimise overlapping

(*c*) To advise and help relevant authorities regarding the training and supply of scientific personnel for pure and applied research.

Constitution

National Research Council The National Research Council shall consist of scientific and technical experts not exceeding 60 in number, the majority of whom shall be elected by non-official scientific organisations, including Universities and institutions of University rank, the remaining number being nominated by the Government of India from among the scientific and technical experts The President of the National Research Council shall be nominated by the Government of India from among the members A Vice-President shall be elected by the National Research Council from among its members A whole-time salaried Secretary shall be appointed by the National Research Council for carrying on its work, who will not be a member of the Council.

Governing Body of the National Research Council: There shall be a Governing Body of the National Research Council which shall consist of the following:

The President and Vice-President of the National Research Council and the Chairman and Vice-Chairman of each of the Boards.

Boards of Research: For the performance of its functions the National Research Council shall constitute the following

Boards of Research from among its own members, each of which will be responsible, within its own particular sphere, for giving effect to the policy of the National Research Council:

1. Board of Scientific Research,
2. Board of Agricultural Research (Soils, Crops and Animal Husbandry),
3. Board of Medical and Public Health Research,
4. Board of Engineering Research,

and such other Boards as may be considered to be necessary

The maximum number of members of each of the Boards of Research shall be 50 The National Research Council shall appoint the Chairman and Vice-Chairman of the Board and shall co-opt eminent scientific workers in different branches in consultation with non-official scientific organisations, Universities and institutions of University rank, scientific departments of the Government and Federations of Chambers of Commerce

Research Committees· For the performance of its work, each Board will be authorised to constitute Research Committees for all important subjects, to settle the objectives of research, indicate the individuals or organisations which could undertake the several component parts of the enquiry, receive and co-ordinate the resulting information, make it available to those who will turn it to advantage and to form a national plan into which all who are in a position to contribute information can fit their particular lines of research. Governing Bodies of National Research laboratories, when established, shall be constituted in consultation with the relevant Research Committees.

II. The Government of India be requested to form development corporations for the performance of functions analogous to those performed by the Research Enterprises Ltd. in Canada. The National Research Council shall be represented on the Governing Bodies of the development corporations.

III. To enable effect being given to the policy of scientific development determined by the National Research Council, the Government of India should make a grant of five crores of rupees per annum.

It was decided further that these proposals be circulated to the Government scientific departments, Universities, learned societies and unattached institutions for expression of their views, and discussed, with a view to their being given effect to, at another symposium meeting to be held at Delhi towards the end of the year at which representatives of the relevant organisations would be invited to be present.

These proposals have been given wide publicity They will be discussed again in the symposium today. I am very glad that many learned societies and scientific institutions have sent delegates to this conference, and I extend to them on your behalf a very cordial welcome Doubts have been expressed whether it is possible or even desirable to bring the whole domain of natural science within the purview of one central council In the Soviet Union, the Academy of Science has long been an integral part of the Government in the planning of scientific and technological expansion in all its branches. There are advantages in such centralisation if the workers are imbued with real team spirit. But where such spirit is absent, the central machinery may wear away rapidly by too much friction. Then again, it has been pointed out, that at the present moment, several departments of the Government of India are interested in scientific research—Departments of Industries, Supply, Labour, Communications, Agriculture, Education and Health. The question has been asked, that supposing the Government of India agree to the creation of a central National Research Council, what should be the relation of this Council with these important departments of Central Government? Some apprehend that such a central council may not be always wise and may not be helpful in developing that initiative in *all grades* of scientific workers which is essential for success in research. The Governing Bodies of some of the existing institutions would wish to be assured that their autonomy would not be ultimately undermined by a generous policy of assisted research in their scientific laboratories. These are some of the difficulties that have been brought to my notice. They are not insurmountable; and I feel confident that given goodwill, they may be removed by patient discussion What I consider essential is that we should all feel that post-war organisation of scientific research is a vital problem which must be lifted clear of the arena of dispute, that it will not do to pay only lip service to the principles of planning and that science must be harnessed to the task of better living in India.

I feel that it will be a great advantage if research in all branches of science and industries were made the special responsibility of a Member of the Viceroy's Cabinet, and the proposed National Research Council with its constituent Research Boards—the Board of Scientific Research, the Board of Agricultural Research, the Board of Medical and Public Health Research, the Board of Engineering Research, etc.—were set up under this Hon'ble Member close co-ordination between a Research Board and the corresponding Development Board being effected by a large number of common membership. The great Departments of Industries, Supply, Labour, Communications, Agriculture, Education and Health in the Central Government would thus not only remain fully cognisant of the progress of researches under the auspices of the National Research Council, but what is more, they will be entrusted with the duty of implementing the results of the accomplished researches through the respective Development Boards functioning under them.

In my address at the last symposium, I pleaded that 0·1% of the national income might be set apart for research and another 0·1% for the training of research workers This was generally accepted at the meeting and it was resolved that to enable effect being given to the policy of scientific development by the National Research Council, the Government of India should make an annual grant of five crores of rupees. I find that I have been too modest The Parliamentary and Scientific Committee in Great Britain have recently made recommendations of a far-reaching character They deplore that in the period 1919-1939 Great Britain began to fall behind other countries like the United States of America or Russia in the scale in which researches were carried out and applied to technological developments in many fields During the present war, British scientists and engineers have demonstrated that their capacity and inventive genius are unsurpassed It is now recognised that in the post-war period in Great Britain, research and its application must be on a far bolder and more imaginative scale than in the period 1919-1939, and the Committee have recommended that Great Britain ought to look forward to spending ten times as much annually after the war on research and development, in order to provide the necessary basis without which British industry and agriculture cannot meet the needs of the future.

I cannot help quoting again from the eloquent address of Professor Hill to which I referred before: 'We must insist that the cheapest and most certain method of human betterment is the improvement, in Benjamin Franklin's words, of useful knowledge. If a country's poor and undeveloped let us spend *more* on research not less: the amount we can possibly spend is insignificant—only 1 or 2% of the national income anyhow—and will bring a very handsome dividend. As Herbert Agar says this is a time for greatness—we must either be great or dead—and one important element of greatness is intelligence. Stupidity and ignorance are not compatible with greatness.'

'In what ways can science help us directly in promoting human betterment? In England now we are contemplating a vast expenditure on housing, in the next 20 years £2,000 million or 2,600 crores of rupees One per cent of that spent on research, on design, materials, building, heating, lighting, ventilation and amenities, will certainly make the new houses many times 1% better, healthier and more efficient We are, in fact, already devoting whatever effort we can spare from the war to research on building We mine 20 crores of tons of coal annually—1% of its cost spent every year on research will certainly improve the efficiency of its utilisation by many times 1% We're intending to spend half at least of that by a joint co-operative effort between Government and the industry There are 60 million people in the Colonial Empire The Colonial Research Committee, under the chairmanship of Lord Hailey, is able to spend £500,000 or 6½ million rupees annually of Government money as soon as research workers are free from their war duties Its purpose is by research to improve the welfare of the Colonial peoples It sounds a lot but it only comes to one or two annas a head Your Department of Scientific and Industrial Research is allowed to spend 10 lakhs of rupees per annum It's doing very fine work for your country, as I've seen already for myself, but the cost is only 1/25th of an anna for each inhabitant of India It could usefully spend ten times as much. Your annual budget now I'm told is 600 crores of rupees; 1% of that is 6 crores. My scientific friends in India would be very happy indeed if they could look forward to anything like that. In England I suppose we spend £50 million a year on medical treatment and to this might be added several times the amount for time and health wasted owing to preventable diseases. Medical research in all its forms does not spend more than 1% of that. The Industrial Research Associations in England spent in 1938 about half a million pounds—a very small fraction of 1% of the annual value of British industrial production. I want my listeners to get one very simple idea into their heads—1%. It doesn't sound very much. Let us aim at giving 1% of national budget, 1% of the value of our industrial and agricultural production, 1% of the loss due to ill-health, 1% of the cost of our food, our transport, our houses, our water, our coal, even our broadcasting, to research—and in ten years we shall find that we're getting back not 1% but 10 or 20 or 40 or 200% in dividends. .'

'If those who call themselves "practical men" object, let us remember Francis Galton's definition of the practical man—"the practical man is the man who practises the errors of his forefathers" . '

'Perhaps in India you will be able to profit by our mistakes One piece of advice, however, I'm confident in giving, namely that it's worthwhile devoting a greater fraction of your national effort to scientific research and technical development and I'd like to leave you with the three words—"one per cent" '

I re-echo his noble words and would like you to press for an annual grant of Rs 25 crores for scientific and production research and training of research personnel. I conclude with the hope that the Government of India will take courage and swim with the current of modern world's enlightened opinion and not cling to cautious, wooden and antediluvian policies which will perpetuate Ignorance, Poverty and Disease in this land.

ANNUAL ADDRESS

J C Ghosh

(delivered at Nagpur, 1945)

I am sorry that I am not present with you at the Annual General Meeting of the National Institute of Sciences of India. As you are aware, early in 1944, an invitation was received by your Council from the Royal Society to send a representative to London to discuss with the officers and Council of the Royal Society the whole question of the establishment and recognition of an all-India Society of eminent scientific workers The Council felt that the President should be the representative to be entrusted with these delicate negotiations. Accordingly I joined the delegation of Indian scientists who were invited by H M Government to visit the United Kingdom to study on the spot how science has been organised and utilised there for the prosecution of the war. I hoped that I would be able to return to India early in December, but the Government of India thought that the Indian Scientific Mission could with advantage also visit the United States of America and Canada so that their experience might become more useful for the post-war planning of scientific training and research in India. Hence it is that I shall be in the Tennessee Valley, USA, and not in Nagpur on the day of the Annual General Meeting

On the 7th of November, we had the privilege of meeting the British Scientific and Parliamentary Committee in the Houses of Parliament. The Committee felt that Great Britain was falling far behind the USA and USSR in the scale in which financial provision was being made for scientific research; they look forward to spending at least four times the present available funds annually after the war in order to provide the basis without which British Science cannot effectively meet the needs of the future. As a matter of fact, the Royal Society appointed at the end of 1943 expert Committees in Physics, Chemistry, Biology and Bio-chemistry, Geology and Geophysics to report on the needs of research in fundamental sciences after the war They estimate that provision will have to be made for one million pounds a year for ordinary expenditure on research in these fundamental subjects 'This figure of a million pounds does not include the capital cost of building new laboratories or extensions or renovations to laboratories, which in many cases are required in order that the increase in staff and research activities can be accommodated These were considered to be a direct responsibility of the Universities and were, therefore, not included in the research bill It also does not include the salaries of (permanent) academic staff (in Universities and Research Institutes for pure science) but it does include the ordinary costs of their research work' It is hoped that a million pound grant will be distributed annually by H M Government through the Royal Society to the Universities for research in fundamental sciences

In India, research is still a responsibility of the Central Government and, I hope, will continue to be so in future. If the needs of Universities and research institutes in the UK, whose resources are incomparably greater than those of similar institutions in India, are being so carefully looked into now, how much more imperative is it for us to make a similar review of our post-war needs of research in fundamental sciences? I hope that the Council of the Institute will take up this matter for serious consideration early next year and put up comprehensive proposals before Government. The Government of India are now considering post-war plans for universal primary education and adequate secondary and technical education; and it is time that they are fully informed of what we consider as reasonable requirements for higher scientific education and research in the country.

The Council of the Institute with the approval of a large majority of the Fellows have taken the momentous decision to transfer our headquarters from Calcutta to Delhi (*a*) on the following conditions: (*i*) that suitable accommodation be made available in Delhi, (*ii*) that an annual grant of Rs. 15,000 be sanctioned by Government to meet the travelling expenses of Fellows for attending meetings of Council; and (*b*) on the understanding that the National Institute of Sciences of India will be granted a Charter and given statutory authority on the model of the Royal Society. It is not possible yet to announce any definite results, but I feel that we have no reason to be dissatisfied with the progress of our negotiations with the Government of India and H M Government I shall be failing in my duty if I do not express on this occasion my warm appreciation of the help which Professor A V Hill has rendered us in this connection He spent the winter of 1943-44 in India as a representative of British Science and as an Adviser of the Government of India on the organisation of scientific research He expressed fully the opinion that the National Institute of Sciences of India is the nearest equivalent in India of the Royal Society and recommended to Government that statutory recognition be given to our Institute as the body best suited by constitution and membership to assume the role of a national academy of sciences such as:

The Royal Society (London),
The National Academy of Science (Washington),
The Academy of Science of the USSR (Moscow).

It is a welcome sign of the time that the Government of India should be taking a keen interest in the development of industrial research in the country. The Council of Scientific and Industrial Research, which has now been attached to the Department of Planning and Development, appointed early in 1944 an Industrial Research Planning Committee consisting of influential representatives of business and science, to report on the steps and measures that should be taken to promote, direct, control and organise industrial research activities in India. In response to a request by the Committee, the Council of the National Institute of Sciences submitted the following memorandum, which I consider of sufficient interest to be quoted in full

'At a symposium organised by the National Institute of Sciences of India on this subject, held at Calcutta on the 27th and 28th September, 1943, and concluded at Delhi on the 30th and 31st December, 1943, it was recommended that a National Research Council should be created, with a Member of the Viceroy's Executive Council as its President, and that it should function through four Research Boards as follows:

1 Board of Scientific Research (Mathematics, Statistics, Physics, Chemistry, Botany, Zoology, Geology, Geography, Psychology, etc)
2 Board of Agricultural Research (Soils, Crops, Animal Husbandry, Fishery and Forestry)
3 Board of Medical and Public Health Research including Medical Science.
4. Board of Engineering Research including Mining, Metallurgy

And such other Boards as may be considered to be necessary.

The President of the National Research Council shall appoint the Chairman of each Board in consultation with the National Research Council. The Vice-Chairman shall be elected by each Board from amongst its members.

It was contemplated that all the existing research organisations should be fitted into the above scheme. The terms of reference to the Scientific and Industrial Research Planning Committee are, however much narrower. They exclude any consideration of agricultural, medical and public health research.

The views of the Council of the National Institute of Sciences of India are as follows:—

(i) There should be created a Board of Scientific and Industrial Research under the direct control of a Member of the Viceroy's Executive Council who should, if possible, be also the controlling authority for scientific research in all branches of knowledge.

(ii) The Board should consist of (*a*) a General Council, of which the Chairman shall be the Member of the Viceroy's Executive Council in charge, and (*b*) an Executive Committee.

(iii) The General Council may appoint Research Committees as approved in the resolutions passed at the Delhi symposium

(iv) Finances: The Central Government should provide an adequate initial capital grant which may amount to at least 10 crores of rupees for bringing into existence the various laboratories for conducting industrial researches. Such industrial researches should be of two categories: long-term research which will include research of fundamental problems and short-term research pertaining to the immediate needs of industries. For the present the following laboratories may be envisaged:

- National Chemical Laboratory
- National Physical Laboratory
- National Metallurgical Laboratory
- Fuel Research Institure
- Glass and Ceramics Research Institute.
- Fertilisers Research Institute.
- Electrochemical Research Institute
- Textile Research Institute.
- Institute of Dyestuffs Chemistry
- Institute of Fermentation Technology
- Radio Research Institute.
- Leather Institute.
- Institute of Food Research and Technology.

(v) Constitution of the General Council and Executive Committee: It is considered that a majority of the members of the General Council and of the Executive Committee should be scientists.

(vi) Existing Research Institutions: The scientific departments of the Indian Universities and the research institutions should be encouraged to improve their research facilities and should be invited to participate in the programme of research that may be laid down by the Board by generous grants-in-aid.

(vii) Training of Research Workers: Funds should be allotted in an adequate measure for the training in research of able post-graduate science students in laboratories of Universities and Research Institutions wherever capable investigators in the permanent staff are available to guide and supervise the work of such students, and the Universities and Research Institutions should be encouraged to develop and maintain permanent schools of research on specific lines by generous grants-in-aid.'

We hope that the Committee will take a very wide view of their functions and make far-reaching recommendations for the benefit of Indian industries and India.

The suggestion that ten crores of rupees should be provided as capital outlay for bringing into being several all-India research laboratories in the essential branches of science and industry may appear extravagant to those who are familiar with Indian conditions only, or with scientific departments of British Universities. In England, I was greatly impressed by many magnificent research organisations outside the Universities, e g The National Physical Laboratory, The Royal Aircraft Research Establishment, The Anglo-Iranian and Shell Group Organisation, The Brown-Firth Research Laboratories, The Shirley Institute and the Imperial Chemical Industries Research Laboratory. The last-mentioned laboratory has in its staff about one thousand able research workers representing almost all branches of science and has a recurring annual expenditure of two million pounds. In the USA, scientific and industrial research has been developed on a vaster scale, and an expenditure of five million dollars a year in a laboratory is not considered at all exceptional. Such laboratories are often integral parts of the giant industrial concerns which dominate American business. But sometimes they are the outcome of private generosity; for instance, the Mellon Institute at Pittsburg. This Institute was founded in 1911. The two brothers, Andrew and Richard Mellon, felt that their vast wealth could not be better used than by establishing a Research Institute which will help manufacturers, who have little research facilities of their own, to develop new products or improve old processes. Such an Institute will be a strong force in the direction of improving the standard of living through discoveries and inventions. The magnificent laboratories built for this Institute in 1937 have set up a new standard for research institutes, even in America.

Pittsburg is the centre of researches on coal in the United States. The Council of Scientific and Industrial Research in India naturally attaches the greatest importance to the study of Indian coals and is anxious to establish a National Fuel Research Laboratory at Dhanbad on an adequate scale even in war time. I was, therefore, anxious to familiarise myself with the nature of investigations that were being carried out in the various laboratories at Pittsburg, which I visited in mid-December. Researches on the production of coke from American coal, on the recovery of by-products and on the design and fabrication of coke oven plants are being carried out in the laboratories of the Research Division of Koppers Inc. in Pittsburg We visited their latest plant at Kearney N. J which handles 1·5 million tons of coal every year The heat balance in the ovens is so perfect that we walked about the basement underneath the ovens, we were told that this space would be used for stores and office purposes.

Production of industrial chemicals by low temperature oxidation of coal is the primary concern of the Coal Research Laboratory of the Carnegie Institute of Technology, Pittsburg. The Bureau of Mines Research Laboratories were primarily interested in the processes of coal analysis, in complete gasification of coal, and in carbonisation both at low and high temperatures In view of the plentiful supply of petroleum available in America there was little interest in the synthetic production of liquid hydrocarbons either by the Bergius process or Fischer-Tropsch process. In 1942, the Bureau of Mines, however, started research on Fischer-Tropsch reaction and in 1944, Congress approved the new synthetic liquid fuel programme which would extend over a period of five years in the first instance. The appropriation for the purpose, for the year 1944-45, has been increased to three million dollars. It is now recognised that the development of the Fischer-Tropsch process offers great possibilities not only for the production of synthetic fuel but also as a source of raw materials for a great variety of chemical products such as wax, fats, synthetic rubber, plastics, etc.

Some of us, who have worked on Fischer-Tropsch reaction in India, cannot help suffering from a sense of frustration when we compare our exceedingly meagre resources with those that are at the disposal of the workers on this problem not only in the USA but also in the UK; and sometimes from a sense of despair at the inadequacy of our facilities we feel like giving up this work altogether Yet the contribution on this subject from the laboratories of the Dacca University and the Indian Institute of Science is generally recognised as of considerable significance I feel that a short account of this work will not be out of place.

The Fischer-Tropsch process originally consisted in passing synthesis gas containing a mixture of carbon monoxide and hydrogen in the ratio of 1: 2, carefully purified from sulphur compounds, over catalysts whose main ingredients were cobalt and keiselguhr; under suitable conditions, as much as 150 grams of liquid petroleum can be obtained from 1 cu.m of synthesis gas Cobalt is a comparatively rare metal, and in times of war is not obtainable in most countries. The same is true of keiselguhr In 1933-34 we carried out laboratory investigations on the use of cheaper and more readily available catalysts like iron and copper for this synthesis. Fischer and Decarrier, by using iron catalysts, could not obtain more than 35 grams of liquid hydrocarbons per cubic metre of synthesis gas and discarded such catalysts as unsatisfactory. Ghosh and Sen obtained a powerful catalyst by soaking 2·5 grams of asbestos with a concentrated solution of nitrates containing 4 grams of iron, 1 gram of copper, 0·25 gram of nickel, 03 gram of thorium and ·004 gram of cerium. The oxides of these metals were deposited from the nitrates in the asbestos fibres by slow ignition, and the asbestos thus prepared soaked with ½% solution of potassium carbonate and dried. At a reaction temperature of 238°, as much as 85 grams of higher hydrocarbons were obtained per cubic metre of synthesis gas. These results were published in 1935 and were considered surprisingly good in Japan. The Japanese Society for the promotion of scientific research financed very generously further developments of such iron copper catalysts with the result that in 1940, the Institute of Physico-Chemical Research in Tokyo produced a catalyst containing iron, copper, caustic potash, boric acid and keiselguhr in the ratio 75: 25: 2: 2: 125 which could be used with purified water gas containing carbon monoxide and hydrogen in the ratio of 1.1 and yield steadily 90 c.c. of oil per cubic metre of gas at 260°. We are now told that the Fischer-Tropsch plants in the Axis countries use catalysts whose ingredients are mostly iron and copper. Indian investigations on this problem, which were suspended in 1935, were stimulated by the war with Japan, and some of the results obtained in the laboratories of the Dacca University and in the Indian Institute of Science appear to be very interesting It is generally believed that nickel is not suitable for Fischer-Tropsch synthesis in that it favours the formation of methane in preference to higher hydrocarbons. As is well known, a catalyst surface is composite and contains points of varying activity. Based on this idea, a catalyst has been developed at Dacca which gave practically no methane when treated with synthesis gas at about 200°-230°, and converted 56% of the carbon monoxide into higher hydrocarbons at a space velocity of 200 c.c. per hour. The composition of the effluent gases after dehydration and absorption by active charcoal remained practically the same as the original synthesis gas The catalyst contained 45·8% Ni, 8·2% Th, 46% keiselguhr and was prepared by precipitation with potassium carbonate, reducing at 350°, cooling in an atmosphere of hydrogen, washing slightly with dilute acetic acid and drying

Again the economies of the Fischer-Tropsch process can be improved very considerably if (1) instead of synthesis gas, water gas can be used as such with very high efficiency of conversion, and (2) instead of atmospheric pressure, medium pressures can be used which will bring down the capital cost of construction of plant per ton of oil produced. The investigations in Bangalore were pursued with these objects in view A study of adsorption of hydrogen gas by catalytic materials indicated that at about 200°C, it is most adsorbed by chromium oxide This led to investigations of catalysts which contained chromium oxide as promoter A catalyst containing 34% cobalt, 4% copper, 2·5% thorium oxide, ·2% cerium oxide, 4·6% chromium oxide and the rest keiselguhr gave very satisfactory results. At a pressure of five atmospheres, and 205°C, and a space velocity of 600 c.c per hour, a steady output of as much as 150 grams of liquid hydrocarbons was obtained per cubic metre of water gas. Fischer-Tropsch reaction is a rich mine which has been scratched merely on the surface. It will yield unsuspected wealth if looked into carefully in the Indian Institute of Fuel Research.

PROFESSOR DARASHAW NOSHERWAN WADIA, FNA*

(Foundation Fellow; President 1945-46)

D N Wadia

Professor DN Wadia, first National Professor of Geology, was born on October 25, 1883 at Surat, Gujarat. He received his MSc degree in Biology and Geology from Baroda College (then affiliated to Bombay University, now Baroda University), and DSc (h c) from University of Delhi (1947) and University of Aligarh (1967). He was the Professor of Geology (1907-1921) at Prince of Wales College, Jammu (now Mahatma Gandhi College), and later served in Geological Survey of India (retired as Asstt. Superintendent). He also worked as Government Minerologist, in Ceylon, Mineral Adviser to Govt. of India; First Director, Indian Bureau of Mines and Head, Raw Mineral Division of the Atomic Energy Commission Dr. Wadia was a Fellow of the Royal Society, London (1957); correspondent of the Geological Society of America, Honorary Member of the German Geological Society, the Belgian Geological Society, Honorary Member of the Geological Society of India (President 1951-52), the Mining, Geological and Metallurgical Institute of India (President 1951-52), the Ceylon Branch of the Royal Asiatic Society, and the Indian Institute of Metals Professor Wadia was a Commonwealth member of the Geological Society of London; General President of the Indian Science Congress (1942, 1943), President of the Calcutta Geographical Society (1938), Inaugural President of the Indian Society of Soil Sciences (1949, 1950), President of the Geographers Association of India (1955), President of the XXII International Geological Congress at Delhi (1964), of the Engineering Geological Society of India (1965-66), and of Geochemical Society of India (1965-67) He was the recipient of the Leopold Von Plakette Medal of the German Geological Society, Meghnad Saha Medal of the INSA (1962), Khaitan Gold Medal of the Asiatic Society, Calcutta (1964), the Sarbadhikari Gold Medal from Calcutta University (1964) and the Padma Bhushan by Government of India (1962).

Professor Wadia devoted his life-long research career in solving the complex problems of Himalayan Geology He also made notable contribution to the knowledge of mineral wealth of the country especially about copper, mica, atomic minerals as uranium and heavy minerals as monazite.

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*died in 1969

PROGRESS OF SCIENCE IN INDIA

DN WADIA

(delivered at Bangalore, 1946)

I greatly appreciate the privilege of addessing this, the 11th anniversary of the foundation of the National Institute of Sciences, on the occasion of its Annual General Meeting. Looking back on our brief history, the year that has gone by must give to the founders of the Institute, several of whom are happily with us to-day in this House, real satisfaction that the organisation, which was founded in 1934 and inaugurated in January 1935 with eight well-defined pregnant objectives, has, after passing some difficult years of growth and edification, entered upon that stage of its career which they had chalked out for it as the National Scientific Society of India. From its very inception, the aim was to form a body suited, by its constitution, rules and methods of work as well as by the representative character and scientific eminence of its Fellows, to occupy the position similar to that of the National Academy of Sciences of Washington or the Royal Society of London. The recent announcement by the Education Department of the Government of India, that Government have decided to recognise National Institute as the premier scientific organisation of the country, is a significant event and will remain the most notable land mark in the early history of this society, which, we confidently predict, is destined to play a most significant role in the scientific progress of the Indian nation. Consequent upon the acquisition of the new status, your Council, after due deliberation, has accepted the following routine duties and responsibilities·—

(*a*) To act as advisers to Government on all scientific matters
(*b*) To co-ordinate the activities of scientific academies, societies, institutions.
(*c*) To distribute grants-in-aid to scientific publications from funds provided by the Rockefeller Foundation and by Government.
(*d*) To administer funds for award of Research Fellowships founded by the Imperial Chemical Industries (India) and also those founded by Government and other public bodies and arrange for the supervision of the work of Research Fellows
(*e*) To do such other things as may be necessary for organising scientific work in India

Scientific meetings are held regularly at present and symposia and discussion meetings on current problems are arranged from time to time A series of *Transactions, Proceedings and Indian Science Abstracts* are being published A consolidated report on the progress of Science in India will be published according to

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The objects of the National Institute of Sciences of India are—

(*a*) The promotion of natural knowledge in India including its practical application to problems of national welfare
(*b*) To effect co-ordination between scientific academies, societies, institutions, and Government scientific departments and services.
(*c*) To act as a body of scientists of eminence for the promotion and safeguarding of the interests of scientists in India: and to represent internationally the scientific work of India.
(*d*) To act through properly constituted National Committees in which other learned academies and societies will be associated, as the National Research Council of India, for undertaking such scientific work of national and international importance as the Council may be called upon to perform by the public and by Government.
(*e*) To publish such proceedings, journals, memoirs and transactions, and other publications as may be found desirable.
(*f*) To promote and maintain a liaison between Science and Letters.
(*g*) To secure and manage funds and endowments for the promotion of Science.
(*h*) To do and perform all other acts, matters, and things that may assist in, conduce to, or be necessary for the fulfilment of the above-mentioned aims and objects of the Institute.

our programme. During the war emergency years, due to difficulty of printing and paper, our publication programme has been inadequate and out of time ; but it is now proposed to entrust our publications to an Editorial Board to help the Editor or Editors in producing the Journal in two fascicles : (A) Physical Science, (B) Natural Science. A Sub-Committee of the Council is now considering the details of this programme which will considerably improve our position in respect of publications.

At a very early date the work of the National Institute of Sciences of India will assume more and more the nature of the work of a National Research Council whose functions may be defined as follow:

(*a*) To plan and watch over the main lines of research and technical developments in accordance with national needs to see that the application of science to public welfare is adjusted to some consistent plan, to advise Government on a common policy and to ensure that available resources for research and developments are distributed to the best advantage of the country

(*b*) To advise and help relevant authorities and institutions regarding the training and supply of scientific personnel for pure and applied research.

(*c*) To distribute grants for promoting approved researches for the maintenance of selected research scholars, for scientific publications and other purposes

For the efficient performance of this work, the National Institute, in consultation with non-official scientific organisations, universities and prominent scientific institutions, the scientific Surveys and Departments of Government and Chambers of Commerce, will, from time to time, constitute Committees of Research for particular science or groups of sciences. Also the Institute will, in future, have to constitute permanent Research Grants Committee. More important duties will henceforth devolve upon our Sectional Committees which will be the proper bodies out of which various Research Committees will have to be formed 'to settle the objects of research in their respective sciences, indicate individuals or organisations which could undertake several component parts of enquiry, receive and co-ordinate the information, make it available to those who will turn it to advantage to form a national plan into which all who are in a position to contribute information can fit the particular lines of research'. A provisional Research Grants Committee has already been established and early in the New Year, the Council will take up the constitution of the new Research Committees

Much the most important event in the Science Year Book for 1945, which will live in history as having brought the end of the greatest war in history, was the surprising rapidity with which research on the use of the energy of atomic disintegration was completed. This is likely to prove one of the greatest revolutions of science and through it of the World Order. Amidst the pious declamations of horror and detestation the use of this discovery has aroused in many parts of the world, scientists should not be deterred from welcoming this new achievement of science which has far more potentialities for good over evil than the majority of the scientific discoveries of the last century We stand close to further great discoveries in this direction. the transformation of elements into other more coveted elements in great quantities is within sight. But, what the ancient alchemists never imagined, we shall also be utilising at the same time millions of horse-power of energy generated in these transformations It is a matter of no small pride to us that, in this great research, India has not been a mere idle spectator Our four eminent physicists have for many years past taken a creditable share in researches on nuclear and atomic physics and on borderline subjects.

At the end of this meeting there will be a special Convention of Fellows of the National Institute of Sciences of India to express their opinion on the solemn need of the time—viz, international control of atomic energy by a World Peace Organisation, restricting its use for the benefit of mankind in general and preventing its vast destructive potential from being employed for nationalistic military ends or for anti-social purposes by any nation or group of nations.

The successful splitting of the uranium atom and the employment of the energy liberated thereby for explosive purposes have so upset the popular imagination that outbursts of wild reproach against the aims of scientific knowledge are heard daily from all sides, mostly from the scientifically advanced countries. It is amusing to hear that there is a vague but growing fear amongst a section of the educated population that if science is not now controlled it will 'wipe out the world and the human race in time' A mass observation report in the Press, taken in 1941, but published lately, states an intelligent citizen of England having confidently declared his belief that 'all scientists should be hanged by the neck until dead' and that in his opinion this procedure had become a public necessity now 'to stem the spate of horrid things which flow from their laboratory benches' This same intelligent citizen advocates a similar fate for 'aeroplane inventors, technicians and other science-mongers'.

The repercussions of these events in India have not been so vocal or demonstrative, but there is no denying the fact that the advancement of scientific knowledge arouses no enthusiasm in the average mind in India and is at times even received with suspicion, if not dislike For a country that has an enormous leeway to make up in fighting chronic malnutrition, insanitation, disease and food scarcity, this mental attitude about the most potent weapon that can fight these evils and work for 'the relief of Man's estate' needs to be changed. Missionaries of science are needed for this task, both in the ranks of Government services and among the public-spirited citizens working for the social welfare of the masses. Scientific societies and academies in India have therefore an extra mission to perform of spreading the gospel of science in all the corners of India. They should, besides their legitimate functions towards their avowed branches of specialised science, ungrudgingly take upon themselves the task of raising science to the level at which it flourishes amongst all ranks of the people in culturally and industrially advanced countries.

Scientific research in India, both in what has been called its 'pure' and 'applied' branches—though, in reality, no such distinction exists—is of late introduction and much lament has been made on its slow growth on the Indian soil. Physico-chemical, mineral, metallurgical, engineering and electro-chemical industries have been slow to take root in India, but, with a fine range of raw products yielded by abundant natural resources of the organic as well as mineral kind, their possibilities are becoming manifest

The Board of Scientific and Industrial Research

These possibilities were scarcely explored even in the initial stage before the outbreak of the war gave a rude awakening to the authorities Government and especially the war Department found themselves bereft of commodities essential for the prosecution of the war. It was during this emergency of insistent demands for defence and security that the Board of Scientific and Industrial Research was born in April 1940. Planned industrial research on the vital, chemical, engineering and metallurgical industries being non-existent, the new organisation under the stewardship of Sir S S Bhatnagar had before it the difficult task of making India an effective source of a number of urgent war supplies. By the end of 1941, India had to occupy a key position as a supply centre for the whole of the Eastern theatre of war. The country's hitherto untapped or indifferently exploited mineral, agricultural and forest resources could not be harnessed all at once. But the technical machinery set up by the Board of Scientific and Industrial Research for the prosecution of industrial research has fulfilled during the past six years expectations and produced results which should be heartening to science workers in India The Board consisting of leading scientists and industrialists has functioned in multiple capacities, both advisory and executive (Council of the SIR), in very trying circumstances. Besides instituting specific laboratory researches on a large number of new products, it offered expert advice on proposals for helping scientific institutions to study problems affecting particular industries and trades and on proposals for the establishment of Research Institutes, studentships and fellowships. The Board has financed schemes of research in universities and other institutions possessing facilities for research in the subjects concerned Altogether there are over 125 such research schemes in operation to-day

The finances of the Board, derived entirely from the Government Exchequer, have been, as one naturally expects in India, on a niggardly scale up till lately, totalling less than the amounts voted for scientific and laboratory research by single commercial corporations such as the Imperial Chemical Industries (London) or the Bell Telephone Corporation of the USA. The success of the undertakings sponsored by the Board, both of strategic and industrial utility, has encouraged the Finance Department to allocate more liberal grants in later years. The vote of the current year according to our information is Rs 30,00,000. These funds have been supplemented by a few donations from the public, including a very generous one of Rs 20 lakhs from the Tata's, for endowing the National Chemical and National Metallurgical Laboratories and a Fuel Research Institute. It is pleasing to mention here that no less than Rs 1,70,000 of these donations is the share of the earnings of the CSIR in the form of royalties and premia on the processes leased out for commercial exploitation, including Rs 25,000 personal royalties of Sir Shanti Swarup, true to the tradition established by himself so early in his career of devoting his royalties from research to the cause of science The scientific work of the BSIR is carried out through some 20 Research Committees which formulate co-ordinated proposals for pursuing schemes in their respective subjects, see to the correct utilisation of the grants voted and plan systematic programmes for further work Some of these Research Committees have already started work on projects of far-reaching utility.

(1) *Metals Committee* under the Chairmanship of Sir J J Ghandy have undertaken extensive research programmes on electro-metallurgy, light and heavy metal alloys, electrical sheet steels, resistance alloys, metal powders, manufacture of metallic manganese, magnesium and beryllium The planning and equipment of a National Metallurgical Laboratory, on a revised outlay of about Rs 50 lakhs, is one of the chief items in the programme of the Metals Committee

(2) *Electro-chemical Industries Committee* have a programme for manufacture of alkalies, carbides, carbon electrodes, artificial abrasives by application of electrolytic, electro-thermal and electro-metallurgical processes

(3) *Fuel Research Committee* have an extensive programme of research and physical and chemical survey of Indian Gondwana and Tertiary coals, their washing, briquetting, blending and low and high-temperature carbonisation, etc. An up-to-date Fuel Research Station is planned and is to be equipped for high-level research on coal fuel

(4) *Heavy Chemicals Committee* have several important research schemes in operation bearing on the manufacture of heavy chemicals such as acids, alkalies, ammonium sulphate and other sulphates from gypsum, phosphatic fertilisers and other heavy chemicals The projected National Chemical Laboratory is under active planning and construction at Poona.

(5) *Plastics Committee* under the Chairmanship of Sir J C Ghosh have correctly estimated the immense importance that Plastics will play in India. Several manufactures have been developed from the indigenous sources and synthetic resins in the Board's laboratories, among which the more notable are unburstable petrol containers, laminated jute fibre-boards, electrical appliances, containers, plastics from vegetable oils, substitutes for glass, etc.

(6) *Glass and Refractories Committee* have schemes for the manufacture of improved ceramic products, optical glass, ceramic colours and glazes and high-temperature refractories, survey and refining of Indian glass and ceramic raw materials. The foundation of the Central Glass and Ceramic Research Institute was laid at Calcutta by Sir Ardeshir Dalal.

(7) *Dye-stuffs Committee* have over a dozen schemes

on various dyes in operation now The processes that are developed for the extraction and manufacture of dyes from vegetable products have already entered commercial exploitation

(8) *Radio Research Committee* under Professor S K Mitra have undertaken investigations on the manufacture of radio receiver sets, valves, condensers, etc, and an atmospheric research station for investigations on upper air for radio-electronic research is being established

The remaining 12 Committees of the Board are engaged in equally important programmes

Additional grants-in-aid made by the Council of Scientific and Industrial Research during the financial year 1946-47 are:—

	Rs
(*a*) Recurring grant to the Tata Institute of Fundamental Research for research in theoretical physics	75,000
(*b*) Recurring grant to the University of Madras towards the establishment of an Institute of Leather Technology	60,000
(*c*) Grant for conducting Building Research at Thomason Engineering College, Roorkee	90,000
(*d*) Grant for setting up a Road Research Institute at an estimated cost of Rs 17 5 lakhs The amount required during 1946-47 for capital and recurring expenditure is Rs 9·5 lakhs	9,50,000

An interesting offspring of the activities of the BSIR was the institution of the Industrial Research Planning Committee, under Sir R K Shanmugham Chetty, in December 1943. This Committee, after a comprehensive survey of the existing facilities for scientific and industrial research in India, presented a report early in 1945, on measures necessary for enhancing these and the co-ordination, direction and development of scientific research in general on modern lines in post-war India. This report deserves careful attention on the various recommendations that it has made, rather than on the features which have been omitted from its purview and which have come in for unnecessary criticism. Its most notable suggestion is the organisation of a National Research Council for India with the following nine functions:

(*i*) To organise and maintain National Laboratories.

(*ii*) To establish and maintain specialised research institutes.

(*iii*) To stimulate pure and applied research in universities by grants-in-aid

(*iv*) To provide for dearth of technical and research personnel by inaugurating scholarships.

(*v*) To stimulate and encourage research activities by Indian industry

(*vi*) To co-ordinate the research activities of the existing Institutes and Government Departments and plan research programmes

(*vii*) To function as a National Trust for Patents

(*viii*) To set up a Board of Standards and Specifications

(*ix*) To function as a clearing house for scientific and technical societies in the country

A Plan of Agricultural Reconstruction

But in the re-building of the new India, industrialisation alone, without agricultural reconstruction and development, may produce retrograde effects on its economy The country's lifeblood is agriculture; throughout the ages this industry has sustained its vast population and only by a gigantic effort in increasing agricultural production can we quicken its metabolism so as to help the rise of other industries demanded by modern times and conditions of living It is heartening to Indian scientists to record here a second momentous advance in the last two years, viz , a plan for building up of India's agriculture through the application of scientific knowledge The 'Memorandum on the Development of Agriculture and Animal Husbandry in India' by Sir P M Kharegat, commonly known as the *Kharegat Plan*, published by the Imperial Council of Agricultural Research, embodies a far-reaching plan of agricultural reconstruction that should receive the widest attention from Indian scientists and the educated public. The salient features of this 'Plan', which envisages the optimum utilisation of all national assets, in the shape of land, water and live-stock and their maximum exploitation by all means known to science and technology, are given in brief outline below:

'The United Nations' Conference on Food and Agriculture places in the forefront of its recommendations the improvement in the level of nutrition and the raising of the standard of living of the people. It considers it an obligation and a primary responsibility of civilised countries to see that their own people have the food needed for life and well-being. The Kharegat Plan tries to determine the extent of action necessary to discharge the above obligations and fixes minimum targets in the production of various foodstuffs from 10 to 300 per cent in excess of the present meagre standards '

The low level of average production per acre in India has been stressed and reasons for that given, the most important of which are: precarious and badly distributed rain fall over $\frac{4}{5}$ of the total cultivated land, inadequate or entire absence of manuring; low standard of cultivation; use of primitive implements; absence of provision against soil erosion; absence of control against pests and diseases; and poorly nourished and managed livestock.

Water-Irrigation: The production of irrigated crops per acre by controlled irrigation is known to be, on an average, 50 to 100 per cent higher than that of unirrigated crops in the same locality As $\frac{4}{5}$ of the cultivated area is unirrigated it is estimated that provision of irrigation facilities can roughly increase production by at least 50 per cent. Measures to achieve this end are. the harnessing of the water of rivers; the lifting of water by mechanical means, direct from rivers and canals; the utilisation of sub-soil water by ordinary percolation wells and tubewells, construction of minor irrigation works such as tanks; and better utilisation of rain water by bunds and terraces and its conservation in the sub-soil. The total cost of the above programme is estimated at roughly Rs 320 crores.

Land Utilisation: For the utilisation of land to maximum advantage, we must:

(*i*) bring under cultivation such of the 170 million acres classified as culturable waste,
(*ii*) check soil erosion by contour bunding, proper alignment and embankment of fields and control of the water in the catchment area from carrying away rich upper surface of agricultural soil,
(*iii*) provide one scientific experimental farm in every division or district,
(*iv*) obtain higher crop yields by improved manuring and scientific husbandry, such as, use of pedigree seeds, control of pests and diseases, etc ,
(*v*) popularise the use of chemical fertilisers, ultimately aiming at the target figure of one million ton of nitrogen per year for the whole of India, at an estimated cost of Rs. 40 crores, and
(*vi*) improve land tenure system and try out the relative merits of consolidated holdings, consolidated farming, co-operative farming and collective farming on the Russian plan

Improvement of Live Stock: Increased production from Indian flocks and herds depends upon the degree of improvement in both the quantity and quality of their food supply and also on bettering the routine of village management There should be adequate increase in the production of fodder, straw, cereal by-products and concentrates, especially oilcakes

A development scheme should be drawn up for each large grazing area for proper grassland management, including rotational grazing, re-seeding, hay-making, etc.

Growing of trees of fodder species in minor forests, construction of water troughs and the supply of minerals and salts to cattle should be undertaken.

Systematic scientific breeding from pedigree stock of farm animals for their economic characteristics, such as, disease resistance, economic feeding, longevity and milk and draught quantities, should be undertaken. For this purpose, some 60 cattle, buffalo and sheep farms are proposed, each of 12,000 acres, or a greater number of proportionately smaller size. Similar breeding farms are proposed for sheep, goats and poultry.

Provision of dairy farms near towns with facilities for the production of milk and milk products by improved methods and with adequate control of adulteration.

The fisheries of the country are to be systematically tapped by provision of rapid transport of fish, their cold storage, processing, development of inland fisheries by planting of suitable stocks in ponds, tanks, reservoirs, canals and rivers and grant of facilities in the shape of boats, nets and implements to the fishermen.

Organisation The plan emphasises that 'the Central Government must take the lead in many matters if progress is to be rapid. On the research side, it must accept the main responsibility for fundamental research and must advise on policy in regard to agriculture and animal husbandry matters of common interest and must arrange adequate co-ordination of effort, if overlapping is to be avoided and maximum achievement is to result in the shortest time It cannot remain entirely aloof from the extension of the results of research into farm practice throughout the country, even though the practical extension of those results must primarily be the function of Provincial or State Departments of Agriculture It must also be in a position to assist financially when funds are needed for encouraging and promoting research, extension, or other action in the Provinces'

For achieving the above end, the reconstruction plan proposes the following organisation:

(*i*) Creation of a Federal Department of Agriculture which would be charged with the duties of fostering agriculture and animal husbandry on scientific lines in their broadest sense and in all their phases. Its activities would include investigations of production and marketing and utilisation of crops and live stock, and the control of diseases and pests to which they are subject.

(*ii*) The Federal Council of Agricultural Research would be the instrument of the Federal Department of Agriculture for co-ordinating scientific investigations in all parts of India.

(*iii*) The existing Agricultural Research Institute (Pusa) and the Imperial Veterinary Research Institute would be expanded. They would come under the Federal Agricultural Council and their primary function would be fundamental research.

(*iv*) Side by side with them would be set up in appropriate regions in India a chain of Commodity Research Stations and Sub-stations, each dealing with problems connected with its own commodity, be that animal or vegetable in origin These Commodity Stations would follow generally the organisation already existing for jute, cotton and sugar-cane Each would be administered and controlled by an Indian Central Committee for the particular commodity

Education and Extension Work This plan draws attention to the fact that 'in the past, the incorporation by the cultivator of the useful result of agricultural research in his every-day agricultural and live stock practices has not kept pace with discoveries, and neither the cultivator nor the country as a whole is deriving the maximum benefit from the expenditure which has been incurred on research and the results obtained from it This unsatisfactory position is mainly the result of failure hitherto of Provinces and States to staff their Agricultural Department on a scale at all proportionate to the territory to be covered and the number of cultivators to be contacted The latter have remained either unaware of the possibilities of improvement or, in the absence of local demonstration, unconvinced of their applicability. In planning for the future, therefore, a very high degree of priority must be given to the provision of staff and other facilities necessary to terminate such a position and to ensure that, for the future, every cultivator in every village not only has the knowledge of the many directions in which he can increase his yields from his holdings and live stock, but puts that knowledge to practical daily use.'

To achieve this end, it is proposed to treat the village as a unit and build up adequate organisation on it. For each village, a village guide is suggested who may preferably be an active member of its own community, who, while cultivating his own land, could give part-time service to act as a link between the technical experts and the cultivators in his own village for an honorarium. In order that adequate attention may be given in future to extension and propaganda activities, in view of their enormous importance in increasing production, it is considered that the minimum average staff in a Province or State should be:

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(*a*) For Agriculture, either one fieldman per union or group of 25 villages, one non-graduate demonstrator per assessment circle and one graduate inspector per tahsil or one *Mukaddam* or *Kamdar* per assessment circle and two graduate assistants per tahsil. In either case, the gazetted staff would consist of one Superintendent or Assistant Director per Division.

(*b*) For Animal Husbandry, one stockman per union, four live stock instructors, two of whom will have veterinary qualifications, per tahsil, two live stock officers, one of whom would be veterinary per district; and one Deputy Director of Animal Husbandry per Division.

Order of Priority: As several years will be needed for the complete execution of this plan, the following order of priority of action has been suggested to ensure development in an orderly manner and to secure the maximum immediate advantages which existing scientific and technological knowledge can confer

(*i*) Training of technical staff required for the execution of different developments contemplated in this plan

(*ii*) Technical surveys for assessing the full possibilities of various developmental schemes, such as potential irrigation resources, anti-erosion measures and wasteland reclamation.

(*iii*) All important aspects of agricultural improvement, which call for practical action by the cultivator himself, would actually begin as soon as the necessary staff can be provided to guide and direct him.

(*iv*) Creation of a Federal Department of Agriculture, Federal Agricultural Council, Federal Institutes of Agricultural and Animal Husbandry Research respectively and establishment of a chain of Commodity Stations

An increased agricultural production of at least 100 per cent within fifteen years over its pre-war level is envisaged by this plan, provided the necessary finance, services and facilities are available A capital expenditure of Rs 1,000 crores for British India is estimated. For a widespread amelioration of 300 millions of our hitherto neglected rural population, which the projected scheme promises, the outlay in money is not beyond the means of Indian finance The groundwork of the Kharegat Plan is that 'scientific research is the basis of all improvements and that it must be put on a sound footing at the earliest opportunity so that India may obtain the best from its major industry'. This is also the voice of all leading scientific institutions of India

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INDIA IN TRANSITION—THE ROLE OF SCIENCE IN THE BUILDING OF NEW INDIA

DN Wadia

(delivered at Delhi, 1947)

It needs no imagination to realise that India today is a country with a great potential. This position has been attained by a process of natural evolution from her great historic past and is not wholly the result of sub-recent history of the last few generations or of the impact of the two World Wars, as is often imagined Much more powerful factors have been operating since the Aryan migrants occupied the Indo-Gangetic plains The rich heritage of three millennia's experience has moulded the course of events during this long eventful history and it would be wrong to attribute to purely local or modern or accidental causes her emergence into a nation that has won its present status and forged the bridges and affinities with the neighbouring continents.

It also needs no imagination to picture that the transition period through which she is passing is fraught with great possibilities both for positive achievement and for total negation or frustration If it is not fully realised that the transition period should be the building period—the period for high resolve and super-sustained endeavour in every field, the time for shedding of shackles of the past centuries, both social and religious as well as political—the transition time will merely switch the country on to the track of backward, non-progressive, featureless countries of the world. If the transition period is utilised in a dynamic, scientifically directed effort to uplift the whole structure of Indian social, industrial and economic life, there is no doubt its magnificent man-power, so far latent, or utilised to a bare fraction of its potential, applied to its great agricultural, water, forest and mineral resources, will lift the country out of its present abnormal economic and industrial depression and put it on the high road to progress and the welfare of its millions

The one agency which can achieve this transformation is science—science in its most comprehensive application to problems of human existence It is not only the mechanical applications of modern science in everyday life—marvellous as they are—and the lessons of fundamental and didactic science which can help build the India of future It is really the scientific method of discovering truth and the ways of nature and the mental attitude it trains in men for viewing the facts of existence that is the great gift of the Modern Age to man It is primarily the scientific approach to problems of life and society in India, no less than the application of science to agriculture and the manufacturing industries, which needs most to be fostered and cultivated in India Looking around us, there is many a day when the newspaper columns on the happenings of the day fill us with dismay at the bankruptcy of science that is apparent in the everyday affairs of our public life and in the basic relations of our major popular parties. Who can doubt that if politics is viewed in the cold analytical light of a problem in human ecology, the biggest hurdle in the path of communal integration of this sub-continent would be cleared and its march to progress speeded? Then the agitating complexes would be resolved and reduced and the varying environs, habits, traditions and cultures of communities adapted into some practical scheme of mutual collaboration for the benefit of the whole race (i.e. the regional grouping of communities which geography and the course of history has brought about during the last 1,000 years) instead of being dissipated in conflicts tending to degenerate the race.

But my present object is to speak on the role of science and research in India in the transition period in developing the basic sources of wealth and well-being, yet imperfectly tapped, in land, man-power, its rivers, forests, minerals and electric power. The first requisite is that India should align herself in her scientific organisation with the progressive countries of the world, while retaining her own individual pattern of organisation, correlated with the traditions and requirements of the country. India's attitude towards science in the past has been lukewarm, hesitating and even patronising and the result of this is becoming manifest in the country's population outstripping its productive capacity in agriculture and industry, instead of these variables functioning exactly the reverse way—increased productivity of field and factory, inducing and sustaining an increased population. The signs, however, of a welcome departure from this indifference towards science are becoming visible in the last few years as our leading men of science are multiplying ties with representative scientific workers of England, America, Russia and the rest of Europe. The contacts hitherto established form a valuable asset, but they need to be strengthened and vigilantly maintained on a wider scale through new agencies, such as the UNESCO A fair number of our scientists have visited Europe and America during the war and later years, in various Missions and Delegations for Food, Agriculture, Irrigation, Dam Construction, Electronic Research, Industrial Research, Atomic Energy Projects, Metals Research, Fisheries Development, Road Administration, UNESCO etc, ending with the Delegation of 14 Indian scientists (13 of whom were Fellows of the National Institute) for the Royal Society Empire Scientific Conference and the Commonwealth Scientific Official Conference. There are besides nearly a thousand post-graduate students, deputed to foreign countries during the last two years for advanced studies in different branches of science and technology. This is gratifying, as trained scientific manpower is our greatest need. But the world contacts of India in matters relating to science must be ever on the increase. It should grow into a healthy two-way traffic in technical information, exchange of material and personnel He will be a narrow-minded and reactionary patriot who will try to hinder this exchange and cross-fertilisation of scientific thought, or oppose a reasonable outlay of the national revenue for achieving these objects and for establishing international scientific liaison offices at Delhi, London, Washington, Nanking, Moscow or Cairo and later in other European and Asiatic centres

A confederation of the scientific workers of the world for the common objective of amelioration of problems of mankind is perhaps yet a distant dream But some wise heads in the Royal Society of London, thought of gathering together science workers of the various countries of the British Commonwealth in a conference to bring about mutual cooperation in the different fields affecting social, industrial and economic welfare and to consider the most practical ways and means for implementing the decisions reached at an early date The outstanding success achieved during the war as a result of the collaboration between scientists of the United Nations stimulated a desire for the continuation of this method of approach in dealing with peace-time problems which are of common good to Britain, India, Canada, Australia, New Zealand, South Africa and the Colonies It was then felt by His Majesty's Government that such a conference convened by the Royal Society was not to stop at questions of scientific collaboration in the academic field only, but that it should be followed by an official Conference of the nominees of the Governments of all the Commonwealth countries, at which conclusions reached at the former meeting should be supported through the background of official policy of the dominions, and plans matured for their full implementation.

The Conference covered a wide field and

included many problems of the greatest general interest to present-day India on Information and Library Services; facilities for travel of scientists in different countries, increased facilities for publication, international liaison offices and their ready access to scientific workers. 110 delegates representing different branches of science attended the Conferences from all parts of the Commonwealth. The two Conferences lasted five weeks and were marked by an atmosphere of the greatest cordiality and desire for co-operation. It was apparent to everyone during its sittings that, under the present state of scientific organisation of the leading world powers and the onward march to industrialisation that had commenced since the war, isolation of a country spelled stagnation and its side-tracking from the main currents of progress The list of 14 subjects that were carefully chosen for the agenda of the Conference is given below It is in these subjects that the need of a long-term research is greatest and it is in them that investment in capital scientific equipment, laboratories and research institutes, yields lasting dividends. Specialists from different countries presented their countries' view-points on each of these subjects and the state of organisation reached in this field in their respective countries A number of steering groups were set up to lead the discussion on each subject and draft appropriate recommendations for consideration by the whole conference at its concluding sessions The main Steering Committee guided the work of the steering groups on the fourteen items on the agenda; on this body India was ably represented by Sir S S Bhatnagar. The work of the Conference was focussed on these 14 subjects:

(1) A survey of some outstanding problems in Agricultural Science in the Commonwealth.
(2) Discussion of the physiological and psychological factors affecting human life and work under tropical conditions.
The etiology and control of infectious diseases and transmissible diseases, particularly those which are insect-borne.
(3) The present state of science of nutrition and the nutritional studies of the indigenous peoples of the Colonies.
(4) Modern methods of mapping and exploration by Air including the use of radio technique.
(5) Measures for improving the dissemination of scientific and technical information within the Empire, including abstracting and library services.
(6) Methods of improving the interchange of scientists.
(7) Discussion of cooperation in the scientific field with existing and projected international organisations.
(8) Measures to secure greater uniformity in physical standards of measurement and the use of units, terms and symbols
(9) Collection and interchange of scientific records and experimental material, including safeguards to minimise the risks involved in the distribution of plants, seeds and animals
(10) Problems of land utilisation and conservation and the various factors affecting Forestry, Soil Erosion, Irrigation, etc.
(11) The need for coordinated surveys of mineral resources of the Commonwealth countries
(12) The natural products of the Empire and the chemical industries that are, or might be, based on them
(13) Post-war needs of fundamental research
(14) International liaison offices

This, Gentlemen, is a highly condensed account of the work of the Royal Society Scientific Conference convened for reconstructing and rehabilitation of the part of the world forming the British Commonwealth of Nations Such is the background of this assembly of nations. The body of its recommendations suggesting an all-round mobilisation of available scientific talent for their implementing is shortly going to be published and is bound to receive serious attention in many parts of the world What is going to be India's response? The question may be asked what has India to gain by it?

The Indian delegates as a team participated in these discussions and had their due share in the shaping of the final recommendations on the above fourteen items. This was done according to a plan previously made at a preliminary meeting held at the Delhi Secretariat, under the auspices of the Hon'ble Member for Planning and Development. Each delegate was assigned one or more subjects on which he had to present India's view-point and its existing set-up and indicate lines on which the future work was to be planned. As the deliberations proceeded they were so impressed with the array of scientific forces brought to bear on the various problems that they desired to frame similar plan of operations for India and to mobilise public opinion in support. Accordingly, a symposium on the subject is being organised in April next for a full discussion by the Fellows of the National Institute of Sciences of India of the ways and means of implementing those of the recommendations of the Commonwealth Conference that have a direct effect on Indian economic and scientific problems. They will then issue a considered and comprehensive statement inviting attention of the present Interim Government for implementation of the recommendations. It will specifically call attention to outstanding needs, suggest priorities and formulate plans for energetic exploitation of the basic sources of wealth, land, water and man-power, with which Nature has endowed India, but which have so far been indifferently utilised.

In this task ahead all should join. The unhealthy distinction on which emphasis is too often placed in India between official and unofficial scientific worker must go. There is no doubt that the Universities, private research institutions and societies will be more and more the spearheads of scientific progress in future. It is, therefore, the imperative duty of all official scientific departments and individuals, with their ampler resources and facilities, to strive to raise the efficiency and prestige of University laboratories and make scientific research independent of personal, racial or communal bias.

It is pleasant to turn from what remains to be done to what has been done, or is being accomplished, to reduce our liabilities on the debit side of the national balance-sheet. The advance that is made in Irrigation Engineering in India since 1860 and the striking progress of the last few years in Irrigation and hydraulic research, no less than the size, number and scope of the new projects, adumbrated under the Central Waterways, Irrigation and Navigation Commission (CWINC), for flood protection, storage reservoirs, land irrigation and electric power generation, have gone mostly unrecorded and even unpublicised in scientific academies and journals. India today occupies a pre-eminent position and leads the world in Irrigation, with its 70 million acres of dry land (out of the 400 million acres usually under cultivation), annually watered by canal irrigation—an acreage greater than the combined total of ten other leading countries of the world. According to Rai Bahadur Khosla, Chairman of CWIN Commission, irrigation canals in India have a carrying capacity of 400,000 cu. ft. per second and the total annual consumption of water for agriculture is roughly 163,000 cu. ft. per second. This large amount, however, Mr. Khosla states, is barely 6 per cent of the available "water wealth" in our rivers, which is running to waste in the sea, often after doing extensive, recurring damage in floods and erosion. Indian engineers are, nevertheless, bringing us nearer to that yet far off era dreamt of by the great Sinhalese King of old, Prakrama Bahu, who commanded his engineers to see that not a single measure of monsoon rain was lost by flowing away uselessly into the sea.

It is a matter of great satisfaction that the Government of India have during the last year taken important decisions in sanctioning large scale operations on a number of hydel power, irrigation and reservoir projects and given a high priority to three large projects connected with the harnessing of the Damodar, the Mahanadi and the Kosi rivers. The great Jog (Gersoppa) Falls project of the Mysore Government on the Sharavati river is emerging into the final stage and a number of schemes are maturing, such as the Bhakra Dam of the Punjab (one of the highest dams to be erected in India), the Rampad Sagar Dam on the Godavari, the dams and reservoirs on the Tungabhadra, the Teesta and the Rihand. Necessary topographical, geological and hydrological investigations by CWINC and other authorities have advanced these projects considerably towards construction stage.

Atomic energy development experiments have aroused the keenest interest in all industrially advanced countries, both for their strategic and defence application as well as for their possible industrial use. Gigantic plants are being erected and are rapidly coming into operation for forging of this new weapon in Man's armoury. The Board of Scientific and Industrial Research has taken the initiative in forming a Committee to consider general problems of atomic research and development in India. Apart from the question of military armaments or of defence, the release of atomic energy for practical purposes in the service of Man has a much greater appeal in India for future social and economic developments of society and for the ultimate moral and spiritual uplift of the people at large. India possesses enviable resources in elements and metals whose fission may yield vast stores of atomic energy. The high potential atomic research of the last three or four years in England and the USA has given great importance to the deposits of Monazite sands in South India that have fortunately remained unexploited for foreign exports during the last 24 years. The relatively large Thorium content in Monazite (8 to 9 per cent TiO_2) and its small but usable Uranium component (0·3 to 0·4 per cent U_3O_5) give to the Monazite reserves of the Travancore coast, estimated at over 2 5 million tons, a strategic and economic value which must be utilised with the greatest circumspection on a planned scheme of long-range development for the good of the country and of the world at large.

The Committee has drawn up a long-range programme of research in nuclear physics and artificial creation of atomic particles to be carried out at the Tata Institute of Fundamental Research, Bombay, under the direction of Professor H J Bhabha and at the Palit Laboratory, Calcutta University, under the direction of Professor Megh Nad Saha, who has created a centre of nuclear and atomic research of high calibre during the last ten years.

Minerals are a rapidly declining asset and the question of ensuring their maximum utilisation for the benefit of the nation is most important. The absence in India so long of a definite mineral policy and planned development of its mineral resources have been responsible for the wrong trend taken by the country's mining industry, which has existed largely for wholesale exports of raw ores and minerals. In this way, vast quantities of several high-grade ores and valuable key minerals have been shipped to foreign countries at minimum margins of profit and the country has received little advantage from its mineral assets either in the shape of direct return or in the domestic utilisation, processing or manufacture of finished or semifinished material. India's resources in minerals like Iron-ore, Mica, Beryl, Manganese, Titanium and Thorium, and Aluminium and Magnesium metals are of considerable magnitude and and of world importance The difficult situations that arose during the two war exigencies have shown their strategic importance. A policy of conservation and progressive development is urgently called for and it is highly reassuring that the Government of India is taking steps to bring under Federal control a number of minerals of all-India strategic importance to the extent to which the regulation and development is declared under Federal Law to be expedient in the public interest. Government have also announced their intention to convene a Conference for formulation of a mineral policy for India and for creating an executive machinery for guiding production, conservation and utilisation of the mineral products mined. The recent expansion and re-organisation of the Geological Survey of India which has made possible the creation in it of separate branches for mineral development, geophysical prospecting and water and engineering geology, are much needed and long awaited reforms. Government is committed to considerable further expansions in future and we can look for the day when the Geological Survey will become, as it is in countries like Canada, USA and above all in Russia a powerful agency for industrial development and utilisation of the national resources. The recent report on Coal by the Indian Coalfields Committee promises some improvements in the long-pending critical problems of coal mining in India, its uneconomic mining methods, waste of superior-grade coal and the loss of millions of tons of fuel by fires, roof subsidences and other preventible causes.

These developments and the progress of work of the Board of Scientific and Industrial Research and the Planned Agricultural Reconstruction, I referred to in my last year's Annual Address, are some of the heartening signs which are beginning to be perceived on the horizon. If the rational harnessing of science to the country's manifold resources is continued on the same tempo as in the last five years, who can doubt that the new India which will emerge from the transitional period will be a country with a strong potential?

Gentlemen, it is in this optimistic refrain that I hand over the office of President of the National Institute of Sciences of India to Sir Shanti Swarup Bhatnagar. I am not uttering a mere customary formula when I express my most sincere thanks to the Institute and to its Council, particularly to the Secretaries, Professor D S Kothari and Dr S L Hora for the hearty and encouraging cooperation that has been given to me during the last two years It is my firm conviction that the National Institute of Sciences of India is going to play an increasingly helpful role in the scientific progress of the country and will give the correct lead to the rapidly multiplying institutions and associations in fulfilling both their social as well as technical obligations to Indian society.

SIR SHANTI SWARUP BHATNAGAR, FNA*

(Foundation Fellow, President, 1947-48)

Sir S S Bhatnagar was born on February 21, 1894 at Behra, Distt. Shahpur in Punjab. He received his DSc degree from University of London in 1921. He was the Professor of Chemistry, Banaras Hindu University; University Professor of Physical Chemistry and the Director, University Chemical Laboratories at Lahore (Punjab University); Director, Board of Scientific and Industrial Research (later CSIR); Secretary, Ministry of Education and Educational Adviser, Govt. of India; first Secretary, Ministry of Natural Resources and Scientific Research (set up in 1951 and linked up with Director, CSIR); Secretary, Atomic Energy Commission and Chairman, University Grants Commission.

Professor Bhatnagar was knighted in 1941; he was the Fellow, the Royal Society, London (1943), Honorary Member (later Vice-President) Society of Chemical Industry, London (1943), President, Indian Chemical Society and Indian Science Congress. He received honorary doctorate degree from University of Oxford, Punjab, Delhi, Banaras, Lucknow, Allahabad, Patna, Agra and Saugar.

Professor Bhatnagar has widely contributed to the knowledge of magnetic chemistry. The relation between physical properties and chemical constitution has been exciting interest from the early days of structural organic chemistry. What are known as colligative properties were useful for this study and were employed. That magnetic susceptibility measurements could be used for this purpose effectively, has been the main theme of his contribution. He has used this method not only for the study of pure chemical compounds but also for the study of solutions, films and colloids He was also engaged in the study of adhesion and cohesion in emulsions. He brought the adsorption film theory of emulsions to a definite form by laying adequate stress on the wetting of absorbed film. The greatest contribution of Dr Bhatnagar is of course the development of CSIR and the Chain of associated national laboratories.

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*died in 1955.

SCIENTIFIC RESEARCH AND EDUCATION IN INDIA

S S BHATNAGAR

(delivered at Patna, 1948)

I am deeply grateful to the Fellows of the National Institute of Sciences of India who elected me their President. This is the highest honour which they can bestow upon their fellow-colleagues and I am thankful to them for this recognition of my humble services to science.

With the great change in the outlook of political India with the advent of Independence, events in the world of science are bound to march forward It is no doubt true that the political developments and rioting which followed the partition of India brought to a standstill the programme of development which was in hand particularly in the northern regions. Our construction programmes of the National Physical Laboratory, National Chemical Laboratory and the Central Glass and Ceramic Research Institute, were completely stopped. With great difficulty we are restarting, though slowly. Nevertheless progress has been spontaneous in many directions. In the Ministry of Works, Mines and Power, the projects for the development of power by damming rivers have made vast strides.

The following projects are well in hand:

Mahanadi Project: Work has already started. This scheme is expected to cost Rs 47½ crores and will be able to produce 350,000 KW of electric energy. Total land expected to be irrigated when the project is completed is 1·1 million acres.

Bhakra Dam: Work has already started. This scheme is expected to cost about Rs 65—75 crores and the total land expected to be irrigated will be about 2 million acres. 300,000 KW of electric energy are likely to be produced.

Damodar Valley Project: Work is expected to be started in a few months' time. The cost of the scheme is expected to be about Rs 35 crores. 300,000 KW of electric energy are expected to be produced when the scheme is completed 8 dams are likely to be constructed.

Kosi Project: This dam is expected to be 800 ft high, the highest in the world and this will be able to produce 1·8 million KW of power Work is expected to be started sometime in 1948-49.

Besides these four projects, several other projects are being actively planned and work is expected to be started in about a year's time. Some of these are: Narbada and Tapti projects, Indrawati project and Godavari project.

Possibility of power development in Assam are also under active consideration.

The Central Government maintains a number of institutes for training and research in agricultural sciences, animal husbandry, veterinary sciences, dairy, forestry and fisheries. The Government have sanctioned schemes or the expansion of facilities for research and training in these institutions The Scientific and Technical Manpower Committee, about whose recommendations I propose to deal later, have recommended that the time has come when a co-ordination of agricultural education and training might be accepted through the creation of an All-India Agricultural Council The proposal is now under the consideration of the Government. The Indian Agricultural Research Institute is expanding facilities for training and research in all the major branches of agricultural sciences. The greatest necessity is felt that facilities for training and research in the basic agricultural sciences are provided for our young men at the highest level so that it becomes less necessary to send young men abroad excepting for specialised training in specific subjects and gaining up-to-date experience of technique and ideas abroad. This was the main purpose for which the Indian Agricultural Research Institute was founded. I am glad to say that it is expanding now on these lines. During the last year the Agricultural Department gave serious consideration to the importance of measures of control of wheat against rust The serious damage to the wheat crop last year which meant a loss of more than a million tons of wheat drew the attention of the Government to the subject. A scheme of research based on the note prepared by the staff of the Indian Agricultural Research Institute—this note has been published in *Science and Culture*—was sanctioned by the Indian Council of Agricultural Research with a view to effectively controlling rust problem. Very important work has already been done and the new scheme aims at strengthening the existing work and expanding further on all India basis the research work on the subject.

Another matter which should receive the attention of all of us is the question of increased production from land. Two reports concerning soil productivity and soil conservation have been prepared and are under consideration of the Indian Council of Agricultural Research.

For some years, the Council of Scientific and Industrial Research has been making efforts to bring into being a number of national laboratories. The National Chemical Laboratory at Poona, the National Physical Laboratory at Delhi and the National Metallurgical Laboratory at Jamshedpur, have already been planned and the work of construction has already started. The Central Glass and Ceramic Research Institute at Calcutta and the Fuel Research Station at Dhanbad are also busy in completing their building operations. The technological block of the Central Glass and Ceramic Research Institute is already working. When these laboratories are ready—they have been unfortunately very much delayed for reasons over which we had no control—they will constitute some of the finest laboratories in the world. Meanwhile the research work in these various fields has also been started at these centres in hired or improvised buildings.

Amongst the new schemes of expansion sanctioned by the Council of Scientific and Industrial Research may be mentioned the following:

(1) A nucleus of Building Research Unit which has started functioning at Roorkee with a skeleton staff and has published results of some interest
(2) A Road Research Institute at Delhi is being actively planned and attempts are being made to secure a plot of land for the Institute on the Muttra Road.
(3) The Council has agreed to the establishment of a Central Drug Research Institute
(4) The Council has also agreed to the establishment of a Food Technological Laboratory.

The Finance Ministry has agreed to provide funds for the effective planning of the Drug Research Institute and the Food Technological Laboratory

The Council welcomes the establishment of the Indian Standards Institution We are particularly happy as this is a child of the Council which sponsored its early establishment.

In the field of scientific and technical manpower, the Scientific Manpower Committee appointed by the Ministry of Education submitted their Interim Report some time ago. The Final Report is expected to be submitted by the end of February next. The Interim Report has been considered by the Cabinet and the recommendations made by the Committee have been generally accepted.

The Committee have recommended measures which the Government should initiate without loss of time in order to meet, to some extent, the existing shortage of scientific and technical personnel. These measures relate to:

(*i*) Expansion of facilities for higher scientific and technical education and training;
(*ii*) Medical education and training;
(*iii*) Scientific and industrial research and training;
(*iv*) Industrial training;
(*v*) Technical training for Defence Services.

The Committee are of the opinion that the present facilities for scientific and technical education are utterly inadequate and in order that the immediate needs of the country for scientific and technical personnel may be met in as short a time as possible, it is necessary for the Government to initiate measures which may start bearing fruit within a year or two. The Committee have expressed the opinion that there should be a fourfold increase in the output of technical personnel so that industrial progress may be possible.

The Committee have recommended that for an immediate improvement in the outturn of scientific manpower the Government should utilise the existing sources, viz., universities, special institutions and the industrial concerns, by helping to create in these places adequate facilities for higher education, research and practical training. Such help as is to be given should be largely in the form of grants for (*a*) the creation of scholarships on a generous scale, (*b*) the purchase of equipment, and (*c*) the opening of post-graduate research departments in the universities which do not have any at the moment.

Some of the general recommendations of the Committee may be summarised below:

(*a*) Top priority should be given to imports of scientific equipment and apparatus for educational institutions and the Government should allow rebate on the import duty on such equipment.

(*b*) Surplus war material of scientific value should be made available to educational and research institutions, free of cost as far as possible.

(*c*) To facilitate the training of additional workers in institutions and industrial concerns, the Government should evolve suitable machinery for expediting building construction at various training centres and also provide necessary funds for the purpose.

(*d*) To overcome the great difficulties experienced by the Government in implementing most of their schemes, the Government should—

(*i*) permit the administrative departments concerned to make direct recruitment to scientific and technical posts in special cases instead of depending on the Federal Public Service Commission;
(*ii*) create a Scientific Service at par in status and emoluments with Administrative Service similar to that created in Great Britain;
(*iii*) improve the salary scales of teachers especially those engaged in technical education;
(*iv*) provide funds to enable institutions to send their experienced staff overseas to visit important centres of scientific and technical education and research;
(*v*) institute a large number of scholarships for post-graduate and research training in institutions in India;
(*vi*) permit the construction of buildings for educational institutions through private agencies,
(*vii*) delegate a greater amount of power than at present to heads of educational and research institutions;
(*viii*) place at the disposal of institutions block grants for implementing the programme approved by the Government, instead of grants from year to year;
(*ix*) consult scientific and technical men at all stages when taking decisions on technical matters,
(*x*) take steps towards maintenance of a National Register of Scientific and Technical Personnel by the Council of Scientific and Industrial Research through the agency of the National Institute of Sciences of India

The keen interest taken by the Prime Minister and the Cabinet of the Indian Government inspires us with a new hope and it looks as if Science will get a chance of service. New opportunities and new responsibilities offer themselves to us and the National Institute of Sciences has to play an important part in building the New India.

Incipit Vita Nova: 'Here begins a new life ' There are moments in the lives of a nation as well which forcibly recall Dante's words, for one glimpse of freedom may spell for a whole people what a glimpse of Beatrice did for Dante With the ushering of Indian freedom on August 15, Indian science too cried out in ecstasy—*Incipit vita nova.*

The tasks of scientific education in this country henceforward have to be vastly different from those assigned to it hitherto. In the past, scientific education has aimed mostly at equipping a number of people for the profession of teaching, or of routine testing, whether of a medical variety or of an engineering or industrial variety. A certain number of such scientific workers were in any case needed to keep the imperial machine going—to build and maintain its roads and railways, to run its communications on modern lines, to serve its armed forces and its administrative personnel, to man the various surveys for collecting the data needed by the foreign exploiter. To some extent the people, no doubt, benefited, but undeniably an imperialist bias underlay the entire activity. The Geological, Botanical and other Surveys collected scientific data but they did so inspired by an imperialist purpose. The linguistic and ethnographic data, collected no doubt often with much skill and industry, could be used for the imperialist political purpose of indicating the moral that no nationhood could be claimed for a mere congeries. The scientific Surveys of India's resources were primarily inspired by the imperialist purpose of the exploitation of these resources by her alien rulers. Even scientific research carried out in India was often not freely available in this country. During the late war formulae and processes evolved in Indian laboratories were often handed over to other countries and since they were industrially more developed, they could utilise them for greater advantage. In a free India science is no longer to be the tool of a foreign imperialism, and its two great tasks now are to develop Indian scientific talent to its utmost capacity so that it can make a worthy contribution to humanity's pool of scientific thought and knowledge, and to develop India's resources so that the lot of the common man in this country may be improved. To raise the economic standards of the common man, it is necessary that the speed of industrialisation be a good deal accelerated. This would require expansion in the available scientific personnel and it is among the immediate tasks of scientific education in this country to meet this demand for enhanced scientific personnel. Indian industrialisation demands an adequate exploitation of her vast power resources. No one will contend that today she has the technical personnel she needs for this task. Again, India will have to develop her science and industry for defence purposes, if she is to maintain her freedom and to pursue an independent foreign policy, or to pull her weight in defence arrangements in a commonwealth or a system of alliances. Under foreign tutelage her scientific workers were not permitted to peep into the secrets of the War Office. But henceforward it is going to be the responsibility of Indian science to see that the Indian defence organisations do not suffer for want of scientific knowledge and scientific personnel.

What is to be the language of science in India? Hitherto science has been taught and studied in this country, from the secondary school onwards through English—though there have been laudable efforts to produce scientific terminology and some scientific literature in Indian languages The new context would not permit this state of things to continue. The teaching of science will henceforward have to be done through Indian languages and our universities and learned bodies and scientists and teachers must now be called upon to take effective steps to make this possible without any impairment of efficiency—in fact the efficiency must be a good deal raised if we are to prove equal to our new big tasks in free India. In a very few years, we may take it, the teaching in the topmost university classes will be through Indian languages, though of course those going up for higher studies will find a working knowledge of one or two European languages essential. Those engaged in research are sure to find a knowledge of English and other European languages almost as necessary as they do at present. But there seems to reason why students in our universities who will be listening to lectures in the science theatres in their own languages should not have a supply of scientific text-books in these languages, though for sometime these will necessarily have to be supplemented by those in European languages particularly in English. Our universities and learned bodies and education departments have to give immediate attention to the task of producing a supply of scientific text-books and scientific journals in Indian languages. The task, I should think, is one which would require the offices of a central co-ordinating agency. The chief hitch at present would be the want of ready-made scientific terminology. This is a problem that requires very careful thought and much expert and erudite labour and it must not be decided in a hurry. The Ministry of Education of the Government of India sometime ago set up a committee to go into this question and so also did the National Institute of Sciences. The Committee set up by the Institute seems to favour, when it informally met, the retention of English for the time being, as a vehicle of thought for advanced scientific knowledge, and the retention of the English technical and scientific terms in scientific writing in Indian languages. Scientific writing in India may have to be done in a number of languages, but it will be stupendous waste of labour if each of these sets about coining its own scientific terms—such an enterprise might cost as much labour as did the Tower of Babel and for science in India its results might be no more propitious than those commonly associated with that monument.

To have a uniform scientific and technical terminology for all Indian languages is a desideratum that all interesting themselves in this problem will do well to bear in mind. In the West the scientific terms generally do not differ much as you pass from one European language to another. The common ancestry of European scientific thought in that of Greece, and the common acceptance of Latin as the language of learning during some centuries, have been of great help in creating this uniformity. The mention of Latin will to many be an inevitable reminder that the potentialities of Sanskrit with its richness of vocabulary, its facility in new formations, its having been the mother of Indian languages, and with its religious and cultural position in India not less important than that of Latin in Christiandom—are no less significant. But that is a question I would much rather not go into here. For the immediate future I think we have to be content with the English terminology, though it is plain this is just 'making do' and not a satisfactory or final solution of our problem. We shall soon start looking for such a solution, perhaps a fresh stock-taking may be necessary after the Constituent Assembly has made its decision with regard to India's national language At the moment all I can say is that we must not lose sight of our objectives and they are·

(*a*) Indian scientific workers must be able to draw upon the world pool of scientific knowledge, and in repayment of this debt their own scientific work must be available as a contribution to this pool in a language which is not too difficult to learn and may have to be English.

(*b*) For the free exchange of scientific knowledge among the various centres in India a uniformity of scientific terminology is essential. It is hoped that the Fellows of the Institute would give the country a real lead in these matters.

The country has witnessed a catastrophe the like of which has not been seen in the world in what has followed the partitioning of India. A large number of people have been displaced and they are all over the place as refugees. Science has not been safe from this tragedy and a great many scientists of note as well as professors and students have been rendered homeless. The Government of India in spite of the vast magnitude of this tragedy have done a great deal to relieve the situation. The Delhi University has come to the aid of the former Punjab University and have taken up the Honours Schools in Chemistry and Physics under their auspices. Attempts are also being made to start camp and double shift colleges so that a large number of displaced teachers and students may be usefully occupied. A deep sense of patriotism pervades the country and the rather difficult problem of rehabilitating medical and engineering students has been satisfactorily solved and all the medical colleges in India have agreed to divide the Punjab students amongst themselves. Similarly the Thomason College of Engineering at Roorkee has absorbed all the Punjab students who were working for engineering subjects. It is the prime duty of the National Institute of Sciences to see that these brethren of ours who have been so displaced are suitably employed. It is much to be regretted that this premier body of Indian scientists has not yet addressed itself to the solution of this important problem. I appeal to the fellow scientists who have gathered here to remember these unfortunate brother scientists and see that any help that is possible is given to them in their domains.

I cannot conclude this address without saying a word about the practical utilisation of results of research in various fields in the new India. Although scientific research is a search for truth for its own sake it will be considered an expensive luxury and no exchequer will vote funds for it unless results of practical utility or for reducing suffering or poverty were the outcome of our investigations and while I should not like to minimise the importance of scientific research for its own sake I must draw the attention of our scientists to the great need of applying their knowledge to the good and betterment of India.

In this connection, it is perhaps not out of place to point out that the utilisation and development of research result is a difficult problem in itself to which considerable thought and time have been and are being devoted in other countries particularly in the United Kingdom, USA, and Canada, etc. It would perhaps be desirable to describe some of the methods employed in these countries to attract the attention of the industrialists and potential individual who is likely to use and derive the ultimate benefit from the research activities. A review of these methods has recently appeared in the British Commonwealth Scientific Office Memo. No. 525 (United Kingdom Scientific Mission Memorandum No. 66/47 dated the 25th August, 1947). The British Commonwealth Scientific Official Conference set up in 1946 a Standing Committee Working Party to determine ways and means of promoting the utilisation of non-patentable scientific and technical data. The Committee contacted various American and Canadian agencies to determine methods in operation in these countries in connection with both patentable and non-patentable discoveries. Of these the methods found to be most satisfactory and now in general use are briefly outlined below.

The methods employed by the Federal and State Agricultural Colleges (USA) in interesting farmers and others likely to benefit by the implementation of their results fall in three categories, viz.:

(*a*) Methods that reach the masses: News, stories, circular letters, radio, cinema, exhibits, bulletins and posters.
(*b*) Methods that reach groups. General meetings, demonstration meetings, leader training meetings, extension schools and study courses
(*c*) Methods that reach individuals: Demonstrations, farm and house visits, office calls, telephone calls and correspondence.

The Bureau of Agricultural and Industrial Chemistry (USA) has given much thought to determining the best methods of keeping industry informed and to getting commercial firms to develop the laboratory scale results obtained in its Regional Laboratories After several years of experimentation, the Bureau has found that the best results are obtained by one or more of the following five methods:

(*a*) Demonstration by pilot plants which show to industrialists how the process can be operated on full production basis. It is the Bureau's experience that if this course is not adopted then more often than not the potentially interested industrialist will not take the trouble to give a new process a tryout
(*b*) Frequently the Bureau enters into a co-operative agreement with industry, i.e. a firm's-plant is used to develop a process worked out on the laboratory scale by the Bureau's staff. To avoid possible jealousy or recriminations from other potential users, the Bureau wherever possible asks the appropriate industrial trade organisation to nominate the firm with which it enters into a formal or informal collaborative agreement.

(*c*) Each Regional Laboratory has one scientist on its staff who devotes his whole time to liaison work between the Bureau and industry. The liaison officers keep industry informed of the Bureau's activities by personal visits and they also endeavour to determine nature of industry's problems and utilise the information so gathered in planning future research programmes of the Bureau. Many large firms reciprocate by appointing liaison officers who work in the reverse direction.

(*d*) The Bureau tries to get itself represented on as many trade organisations as possible. This has been found to be one of the best means of winning industrial confidence and ensuring interest in the Bureau's research activities.

(*e*) The Bureau makes the fullest possible use of publications, encouraging its scientists to publish their research findings in a wide variety of recognised scientific journals.

All these methods and more will have to be adopted by us in India to make science really effective and understandable to masses. Realising the importance of this aspect the Government of India set up an Industrial Research Utilisation Committee in 1941, a year after the creation of the Board of Scientific and Industrial Research. Since April last this Committee has been replaced by an Industrial Liaison Committee whose functions remain the same as those of the Utilisation Committee. The success of similar utilisation methods will show even to the lay Indian public the great advantages of scientific research.

To take one concrete case only, it is estimated that vegetable oil lubricants valued at Rs 5 crores were produced by the oil companies from the processes worked out by the Council of Scientific and Industrial Research The Council did not derive any direct monetary benefit from this process but if the oil companies made a nett 10 per cent profit on these, they paid taxes on Rs 50 lakhs profit and if this figure is worked out it will come to quite a substantial amount. In addition to this some 50,000 tons of shipping space with its sea freight and handling charges was saved and if this is calculated, the savings will amount to a handsome figure. Similarly, antigas cloth valued at over 1 crore of Rupees was manufactured from the Council's formula. Here again the Council did not derive any direct monetary benefit but the indirect benefits to the country's economy will be found to be considerable

There are, however, processes in which both direct and indirect advantages are obtainable and enhance the value of research in the eyes of financially minded individuals and corporations in the country.

Amongst the indirect benefits may be mentioned the increased earnings in income-tax, super-tax, excess profits tax and corporation tax, besides provincial and local taxes, which accrue to the Central Government as a result of the profits derived by industry from the Council's processes To these might be added the benefits derived by the country's economy from savings in exchange resulting from diminution of imports of products developed from several of the processes. In addition to these the industries and processes developed have provided employment to a considerably large number of men and the provision of this additional employment of labour brings in its train innumerable benefits which it is difficult to detail.

Before I close, it is my pleasant duty to offer a hearty welcome to the foreign delegates who are attending the current session of the Indian Science Congress. It is very gratifying to learn that an Australian Scientific Delegation which is visiting this country on the invitation of the Government of India for the first time is expected to be present in Patna in time for the Science Congress. These visits have amply shown the growing signs of internationalism of science in India and have proved that science is really international in character and transcends politics. To these foreign delegates India's young scientists give the assurance that in the new India they will prove their altruistic interest in science by constant collaboration with their colleagues all the world over and by working disinterestedly in the cause of scientific research and development. It is only through the efforts of the scientists of all countries that a real United National Organisation can emerge.

PRESIDENTIAL ADDRESS

S S Bhatnagar

(delivered at Allahabad, 1949)

It is my privilege to speak to you once again this year at the annual session of the National Institute of Sciences. I am most happy and proud that this honour has fallen to my lot again. The year under review has been a most momentous one. The joy of our independence was marred by a tragedy the scars of which will remain on the Nation for all time to come. I refer to the cruel assassination of the Father of the Nation, Mahatma Gandhi. Our orphaned Nation under the able guidance of our national ministers, has despite this tragedy, proceeded with the work of national development

Our National Government is anxious that India should take her rightful place in the vanguard of the Comity of Nations in all spheres of activity and in the field of science in particular. It is fully realized that without science industrial development cannot proceed apace nor the standard of living improved. In pursuance of its policy to develop science in India, our National Government created from the 1st June, 1948, the Department of Scientific Research in order to give scientific research the identity and importance that is due to it in the modern world This Department is directly under our national hero, the Prime Minister. The Department of Scientific Research has been assigned some of the important scientific activities which were scattered in the past among several ministries. The main functions of the department are to co-ordinate research, give scientific advice to Government Departments, finance *ad hoc* scientific research in Universities and Research Institutes, deal with *ad hoc* research fellowships in subjects in applied science, and carry out all work in connection with the International Council of Scientific Unions and the International Scientific Unions. Work in connection with the development of atomic energy has also been placed under this new department. An Atomic Energy Commission consisting of Dr H J Bhabha, Dr K S Krishnan and myself has been set up to take stock of our resources of atomic energy and to plan for future development. To co-ordinate scientific work in the various ministries of the Government of India, a high level committee of scientists has been set up. The work of this committee is to organize team work, avoid unnecessary duplication and plan new scientific projects During the short time that the new department came into existence it has paid out grants to Learned Societies and Research Institutes, totalling over Rs. 14 lakhs and it is anticipated that further grants amounting to about eight lakhs would be paid out before the financial year closes A notable achievement is the creation of a National Professorship of Physics under the Department of Scientific Research. This is the first National Chair and it will fittingly be held by our honoured friend and colleague Sir C V Raman at the Indian Academy of Sciences at Bangalore.

It is a matter of special pleasure for me to record here the appointment of Dr D S Kothari, our Honorary Secretary, to the newly created post of the Scientific Adviser to the Ministry of Defence. Dr Kothari has lost no time in setting afoot schemes to make a beginning with a scientific organization for that ministry. The need for a strong scientific research organization for defence is too apparent to need any comment here. But I can say that our Government is fully aware of it.

Professor PMS Blackett was invited during the year by the Ministry of Defence to advise them regarding the setting up of the proposed scientific organization and other scientific matters pertaining to defence. His advice was very helpful, not only in regard to scientific research in relation to defence, but to those of us who had intimate discussions with him on every subject. It was, indeed, a rare pleasure to us that almost immediately after Professor Blackett's return to England, the announcement was made that he had been awarded the Nobel Prize in Physics. This is a fitting recognition of his great pioneer work in the field of nuclear physics.

Sir Alfred Egerton and Sir Ben Lockspeiser visited this country as members of Quinquennial Reviewing Committee of the Indian Institute of Science, Bangalore. Advantage was taken of their visit and they came as far as Delhi. During their stay in Delhi they were good enough to discuss important scientific matters with the Ministries of Defence, Industry and Supply and the Department of Scientific Research They also delivered lectures under the auspices of the National Institute of Sciences and the Council of Scientific and Industrial Research.

A matter of considerable importance to University education is the appointment by the Government of India of the Universities Commission to enquire into and report on the conditions and prospects of University education and advanced research in India and to recommend a constructive policy in relation to their special problems and the needs of the country. The development of science and industry in this country will need a large potential scientific man-power. While National Laboratories and Research Institutes will play an ever increasing part in furthering the application of science to industry, it is clear that ultimately we have to depend upon the Universities for an even and constant flow of scientific workers and leaders imbued with zeal and zest for research. The fast changing world conditions and the new role of science necessitate a vital change in the outlook of the Universities and the Government. I am sure that the Universities Commission will succeed in their difficult task and the Government will be willing to provide funds to finance the reorientation necessary in our system of education. I had on a previous occasion quoted an extract from a memorandum which the Association of Scientific Workers of the UK had submitted to the University Grants Committee of the Treasury. It would not be out of place to quote that again.

> 'We reiterate, then, our plea for the utmost vision and flexibility in budgetting for the development of science in the universities. Where the flowering of intellect is concerned, any accurate prediction is impossible. We are convinced, however, that peace can see at least as rapid a growth in all fields of science as war has brought about in some special applications. The only proper attitude for an enlightened community is to make available the financial and material resources appropriate to each stage of development. We are far from being in sight of either the limits of science or the end of our reserves of intelligence. Bold and flexible thinking is therefore the prime necessity in framing postwar policy for the universities.'

Universities have been rightly regarded as the fountain-head of knowledge and it is in their free atmosphere that we should look forward to vigorous pursuit of fundamental research Fundamental research is the source from which extraordinary applications are likely to emerge and unless we keep ourselves in the forefront of fundamental work it is unlikely that we would make much original contribution to applied research. I would make a special plea to our Universities, our Research Institutes and our Learned Societies not to slacken their support for fundamental research. The bounds of knowledge are infinite and I would urge our youngmen to follow in the wake of our great scientists and blaze the path of the better world of tomorrow.

I may say here a few words about our National Laboratories. Dr Sir KS Krishnan has been appointed Director of National Physical Laboratory, Delhi; Dr George Sachs from USA has joined as Director of National Metallurgical Laboratory, Jamshedpur; Dr J W Whitaker is the Director of the Fuel Research Institute at Dhanbad and Professor J W McBain, the celebrated chemist has been selected as Director of the National Chemical Laboratory at Poona and is joining shortly.

The plans for the setting up of the following new laboratories are well underway:

Road Research Institute.
Building Research Station.
Central Drug Research Institute
Central Leather Research Institute
Central Electro-Chemical Research Institute.
Central Food Technological Research Institute.

I need not stress how much the creation and development of national laboratories are in the interest of the Nation. We have only to turn to other advanced nations of the world, to see how this work is being given the first priority everywhere I am glad to state here that in the case of the new National Laboratories, the Provincial Governments are taking a very keen interest and have offered free land and buildings for this purpose. The Government of Mysore have just given a magnificent palace worth about Rs 50 lakhs for the Central Food Technological Research Institute. The UP Government have offered buildings and land worth several lakhs to house the Central Drug Research Institute. I must also gratefully acknowledge the munificent donation of Rs 15 lakhs made by Sir Alagappa Chettiar to be used for the construction and equipment of the Central Electro-Chemical Research Institute at Karaikudi. I hope that other wealthy industrialists will follow his example and put their hands deep into their pockets to give donations for the construction of national laboratories and other scientific activities of our country. I feel sure that my appeal will not go unheard.

I have, with an eye to the future, repeatedly urged that Co-operative Research Associations and Laboratories should be set up by industry. I am glad that one such Research Institute is being planned by the Ahmedabad Textile Millowners Research Association and that the textile millowners of Coimbatore have also formed a Research Association and are contemplating the establishment of a Textile Research Laboratory.

There is an old saying and a very true one that 'great things never begin as great'. The start that has been made in Ahmedabad and Coimbatore is a good augury for the future May I once again plead with the industrialists of the country that they should make an effort to foster the growth of co-operative research associations and laboratories, for from them must spring not only greater efficiency and output in the industries concerned, but such associations would foster among the members a sense of discipline, a sense of loyalty and a courageous outlook for the future.

Perhaps the most notable event of the year for the National Institute of Sciences was the acquirement of land in New Delhi on which is to be built the permanent home of the Institute It was an uphill task to get this piece of land and in spite of opposition from several quarters we, however, succeeded in getting the plot of land we wanted The Hon'ble Prime Minister kindly laid the foundation stone of the building of the Institute. It is indeed to be regretted that the construction could not so far proceed beyond the laying of the foundation stone. This is due to many causes, the chief of which is the urgent need of the Ministry of Relief and Rehabilitation which has made it impossible for us, in the face of the needs of the people for housing, to press for priorities of a high order for this building. The needs of the people had to come before the needs of a building for the Institute. The Government when it gave the land, did not lay any conditions that any price would have to be paid for the plot, but recently it has been stated that a price would have to be paid. The Government attached no conditions when making us the gift and we feel that the Government is committed to let us have the land free of any charge. The site chosen was preferred because it was nearer New Delhi than the land in the University enclave which had been offered to us by the University of Delhi. Plans for the building have now been approved and it is hoped that the construction work will shortly proceed with utmost vigour. If nothing untoward happens I do not see any reason why our Institute should not be housed in the new home during the present year, a home befitting the dignity and status of this premier scientific society in India.

Before I conclude, may I touch on one or two problems which concern us greatly. As you are aware a Scientific Man-power Committee was set up by the Government. The interim report of this Committee has revealed a serious shortage of scientific man-power. The report of this important Committee which is now being examined by the Government of India stresses the need for training scientific and technical manpower so as to equip our educational institutes, research organizations and industries to deal with the pressing problems of national reconstruction and development adequately and efficiently. The Council of Scientific and Industrial Research is compiling a national roster of scientific and technical personnel available in the country today with a view to utilize the personnel to the best possible advantage.

Burke's statement 'experientia docet'—'experience teaches' might help us here. The youth of today must blaze the path of tomorrow and if we are to make them great we must catch them young. If we turn our eyes to America, we would see how that great country has organized science clubs which serve as a recruiting ground for scientists of exceptional ability. Such clubs are found all over America. There are about a score or so of members in each club and such clubs are functioning in more than 14,000 Junior and Senior High Schools. The clubs are administered by a Science Service which conducts annually a Science Talent Search through which promising boys and girls are selected for further training, taking into account the school record, aptitude and merits of essays on research subjects. The accepted standing joke is that a Professor is an absent-minded individual, and while I would agree that this is *not* true, I would say to our Professors of today 'do not be absent-minded as regards the youth of to-morrow', for it is your duty to inculcate a love of Science in the young and train them so that they could go out independently in search of truth through the medium of science. Can this be done? Yes, it can, if we will make up our minds to gird our loins and to conquer our shortage of manpower by labour. We may follow the experience of America and start science clubs for, if they do nothing else, they will inspire our youngsters with a love of science and that in itself is no small thing.

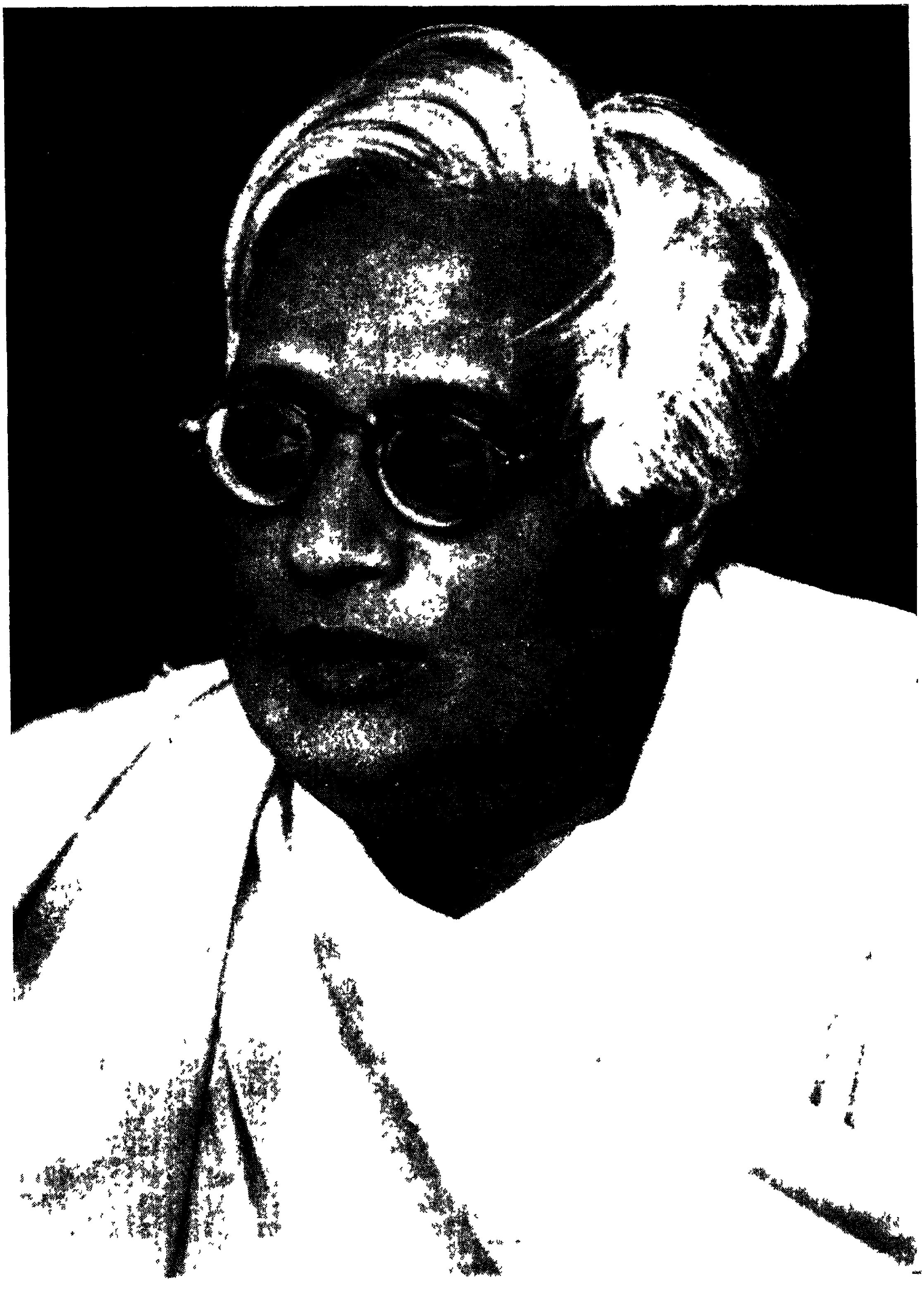
Science knows no barriers, no boundaries, for it exists to alleviate the miseries of mankind The discovery of Atomic Energy has opened a new field. As days go by, we are learning more and more of what atomic energy can do to remedy the ills of the people. The fields of investigation cover Medical Therapy, Animal Physiology, Chemistry, Physics, Plant Physiology, Industrial Research, Bacteriology and Microbiology and Power Production Pursued to its proper end research on atomic energy can make this earth a veritable paradise and it is my earnest hope that the scientists of today will do all that they can to make the millennium come true

Before I close I must congratulate you on your selecting Professor S N Bose as my successor which is a guarantee that the affairs of the Institute would be in competent hands. His fame as a scientist not only in the subjects of Physics and Mathematics but in many other fields such as Chemistry has travelled far and wide. His interests in humanities, art and philosophy are no less profound. He is an idol of the student community and a friend of all interested in science whether high or low. I wish him the best of luck and happiness in his endeavour to raise India through Science.

I hope that this occasion at which we have met under such happy circumstances will be repeated again next year when we will be able to record another year of work and achievement.

Professor Satyendra Nath Bose, FNA*

(Foundation Fellow, President, 1949-50)



Professor S N Bose was born on January 1, 1894 in Calcutta. He received his MSc degree in Mixed Mathematics from University of Calcutta in 1915 securing first position and establishing a record which is held even to date. He was the Professor and Head, Department of Physics, University of Dacca and University of Calcutta and Vice-Chancellor, Vishwabharati University. Professor Bose was Fellow, the Royal Society, London (1958); General President, Indian Science Congress (1944); President, Indian Physical Society (1945-48); Member, Rajya Sabha, Indian Parliament (1952-58), National Professor of Physics (1958-74). He was the recipient of DSc (h c) degrees from University of Calcutta, Jadavpur, Allahabad, Delhi and Indian Statistical Institute and Deshikottama from Vishwabharati University.

Professor Bose will always be remembered for his 'Bose Einstein' Statistics (1924) and his contributions to Einstein's Unified Field theory (1953-55) In the former, he pointed out conceptual mistake in Maxwell-Boltzmann method and showed that no distinction can be made between the individual photons. The statistics of Bose and Einstein when applied to light photons yields Radiation Law. Professor Bose's work, alongwith its subsequent development by Fermi, provided the basis for dividing all elementary particles into two neat categories, the *bosons* after Bose and the *fermions* after Fermi. For his contribution to Einstein's Unified Field Theory, Professor Bose realized the inability of the experts to find exact solutions of the field equations. In the geometrical aspect of the theory, it is important to solve sixty-four equations with affine connections and the metric tensors and their derivatives. During 1953-55, he published five papers solving the above problems. These papers are believed to be mathematical *tour de force*.

PRESIDENTIAL ADDRESS (Summary)

S N Bose

(delivered at Poona, 1950)

The President, Professor SN Bose, thanked the Fellows for his re-election for a second term. He gave a short review of the work of the Institute during the past year and laid stress on the good work that the Institute was doing in distributing Fellowships to scholars attached to different research institutions. He was glad to note that the scheme of fostering research was bearing good fruit and that a number of interesting papers had already been published during the year by the scholars of the Institute which had been received favourably in the scientific world. He hoped that with more generous grants from Government, the Institute would be able to contribute substantially to the cause of scientific progress in India.

He remarked that the Institute had felt the need of a home of its own at its headquarters for some time, and he was glad to be able to report that the negotiations for the acquisition of land on lease were complete and a suitable grant for the construction of a building, had also been received from the Government. During the year under review, a number of Fellows of the Institute had attended different international congresses and conferences in various countries and he hoped that, in future, this would continue and more Fellows would be able to go abroad and thereby promote goodwill and cooperation in the scientific world. He was glad also to know that a number of scientists of eminence from abroad were attending the Science Congress and had come also as visitors at the Annual Meeting of the Institute. He extended to them a very cordial welcome and hoped that their visit and their presence would give enduring stimulus to scientific activity in the country.

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*died in 1974.

DR SUNDER LAL HORA, FNA

(Foundation Fellow; President, 1951-52)

Dr SL Hora did his MSc from Government College, Lahore (now in Pakistan). He joined Zoological Survey of India under the leadership of Dr Annandale and after serving ZSI in various capacities, he retired as its Director.

Dr Hora worked on various aspects of zoology including physiology, systematics, bionomics, ecology, evolution, zoogeography, paleogeography and history of zoology His main contribution was in the field of taxonomy of fishes He not only studied fishery systematics of Indian fishes but also of all neighbouring countries such as Afghanistan, India, Burma, Malaya, Thailand, China, Indonesia and Iraq He advocated 'Satpura Hypothesis' by observing fauna of Malayan range and Peninsular India and attributed it to the migration from eastern regions to the western *via* the Satpura Range of mountains of Central India.

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*died in 1955.

DAPTATION AND EVOLUTION

L Hora

elivered at Calcutta, 1952)

ı selecting an alternative subject for my ldress, *I have been greatly influenced / the correspondence in the recent issues ' *Nature* received in this country during e last six weeks or so. In the issue of ptember 8, 1951, Dr A J Cain raised e question of the value of 'So-called on-adaptive or Neutral Characters in volution'; and, in my view, rightly ncluded 'that those characters or varia- on patterns that have been described as on-adaptive or random should properly described as "uninvestigated". One ust not assume randomness (or selection) ithout proof'. Professor G S Carter (1951), commenting on Dr Cain's observations, ggests that we must accept 'non-adaptive olution as theoretically possible, and, ıtil it is shown to play no significant part natural differentiation we must give it a ace in our general view of evolutionary eory'

seems to me that there is considerable nfusion in dealing with the subject of daptations' and their significance in ganic evolution. In fact, political ideolo- es have become intertwined round this bject with the result that in certain untries freedom of thought in science now denied to individuals who hold ews for or against adaptations and heritance of acquired characters.

attempted to elucidate the problem of laptations in 1930, when dealing with e ecology, bionomics and evolution of e torrential fauna. I asserted then 'that olution is no more than the adaptation organisms to environment' and that tructural modifications are produced rough changes of functions'. Further udies, both in the field and the labora- ry, have now convinced me that changes ı environment initiate functional changes in organisms as a first step in evolution and that such functional changes ultimately lead to structural modifications. The repetition of this sequence of events at shorter or longer intervals has determined the rate of evolution during various epochs of the earth's history and among diverse groups of animals. To substantiate this hypothesis, I shall first refer to some previous observations of other workers and then place before you the nature of the evidence that has influenced me to come to these conclusions

The traditional viewpoint

In his Bancroft Memorial Lecture, Professor Frederic Wood Jones (1931) gave a comprehensive historical review of the concept of adaptations and showed how this point of view has been changing through the centuries. He starts with the Galenical Outlook of the 2nd Century AD. The earliest clear conception of the phenomenon of adaptations is, however, given in *Suśrutasamhita* where the correlation between the form of fishes and their respective environments is discussed (*vide* Hora, 1935) A free translation of the relevant Sanskrit passage reads thus.—

> The river fish are bulky in the middle because they move with their head and tail; the lake and tank fish are similar to the above but are characterized by a relatively smaller head; the spring and pool fish, as they have not much space to move about, are extremely deep behind the head; the fishes of the torrents are traditionally well-known by the possession of two characteristics, the greatly flattened body on account of their habit of crawling with the chest, and a relatively reduced anterior part of the body.

Unfortunately the age of *Suśrutasamhita* is not at present definitely known. Some scholars place it as early as 600 BC while others consider the present text only as old as 200 to 500 AD. Whatever may be the date of this work, it can be stated without any fear of contradiction that the concept of adaptation brought about by environmental factors was well-known to the ancient Hindus.

Annandale on adaptations

In the study of adaptive evolution, the most outstanding work of the late Dr N Annandale seems to have been lamentably ignored but modern students will find in it a wealth of accurate information unrivalled for its clarity of thought and lucidity of expression. He was the foremost naturalist of his time and it was always his habit to study animals against the background of their respective environments. I shall here draw attention to two of his papers written just before his death in April 1924 Firstly, in his Presidential Address to the Eleventh Indian Science Congress in 1924 on 'Evolution—Convergent and Divergent', he stated that 'A simple explanation (of evolution) becomes more and more impossible and environment with its unlimited gradations assumes an ever greater importance. *Indeed it seems hardly too much to say that evolution is ultimately no more than adaptation of organisms to environment*'. (Italics are mine.) Again, in dealing with the evolution of the shell-sculpture in fresh-water snails of the family Viviparidae (1924*a*), he stated.

> 'My explanation of the phenomena discussed in this paper implies an acceptance of the doctrine of the survival of the fittest and at the same time a firm belief in the inheritance of one kind of acquired character. The traumatic injury of an individual can probably not affect the race, *but unless we assume that the long-continued and gradual influence of environment can do so it is difficult to see how adaptive characters have ever arisen.* The very existence of such characters may be denied by observers in a laboratory or a garden plot, but in tropical nature they are continually being forced on the notice of the field zoologist'. (Italics are mine.)

Doctrine of the survival of the fittest

Annandale's acceptance of the doctrine of the survival of the fittest, it will be observed, is not Darwinian for variations in the sense used by him are not random nor are they selected by Nature from any haphazard lot but they are due to the 'long-continued and gradual influence of environment' and are thus acquired by the individual as an adaptation towards the external conditions of its existence. Nature is undoubtedly a very hard task master and, whatever may be the source of variations, the doctrine of the survival of the fittest must hold good. What I believe is that the animal, while still capable of growth, responds to the new situation by a slight alteration of growth; and, having thus responded successfully hands over to the next generation an increased capacity to respond, which is continually increased generation after generation till it becomes firmly engraved on the hereditary power. This implies that there are no random variations and that 'variation is due to the different efficacy with which the individual responds to the influence of the environment and that this is due to the varying degree of *vigour* possessed by the animal and that vigour is the one thing which varies continually (probably due, I think, to the position of the germ-cell in the genital organ and its varying amount of nourishment) and that natural selection chooses not the random variation but the individual which is most responsive to the environment' (quoted from a letter of Professor E W MacBride to the writer, datde November 8, 1928). The point made out by Professor MacBride is that one has not to consider the survival value of a character under study but of the individual as a whole, for an organism is a combination of many characters showing responses to unlimited factors in its environment.

Adaptations are functional modifications

From what is stated above, it is implicit that all adaptations are functional and that when in the economy of life of an organism a particular morphological structure becomes non-functional it persists for some time as a vestigeal organ. I shall take here a very simple case of the modification of the air-bladder in hill-stream fishes. In most of the sluggish-water Cyprinid fishes, the two-chambered air-bladder is well-developed to serve a hydrostatic function. When a fish enters fast-flowing waters, buoyancy will be a disadvantage, for the fish must tend to live near the bottom or in fact it must take to the ground habit of life. We have various species of *Garra*, for instance, in which we can correlate the reduction of the air-bladder with the development of the adhesive disc and the swiftness of the water in which the various species live (Hora, 1921). In loaches of the genus *Nemachilus*, I (1930*a*) showed how the air-bladder becomes reduced under the influence of stronger and stronger currents and when the air-bladder is so reduced and enclosed in bone that it cannot respond to the external environmental conditions, it is left alone as a vestigeal organ. Thus a new air-bladder is developed in species of *Nemachilus* (=*Diplophysa*) which inhabit lakes or other deeper waters at high altitudes in Central Asia. Here we have a remarkable instance of the normal functional air-bladder undergoing structural modifications induced by the environment to ensure proper adjustment of its functions to the needs of the organism concerned. So long as it is sufficiently plastic, it goes on reacting to the external conditions of its existence, but the moment it is reduced beyond a certain stage it becomes vestigeal and if there is need for such a structure for the functional activities of the fish, a new air-bladder makes its appearance. Moreover, though functionally the new bladder may be similar to the old normal bladder, morphologically it is different, for the pneumatic duct in the normal bladder opens in the constriction between the two chambers while in the new bladder it opens at the anterior end. What differences in the environmental factors or genetical variations have produced these dissimilarities, it is not possible for me to say, for the finer gradations between the two environments still remain to be investigated.

The reduction of the air-bladder in hill-stream fishes is correlated with the ground habit of life. This assumption is justified, for whichever group of fishes, Carps, Catfishes, Gobies, etc., has entered swift currents, the fate of the bladder has been the same. Furthermore, if the ground habit is a necessity in other types of habitats, such as the estuaries, marshes, etc., the air-bladder becomes reduced in more or less the same way as in hill-streams. It follows that adaptations are functional irrespective of types of environment.

Animal plasticity and environment

A remarkable instance of structural modifications was observed among the two groups of individuals of a species of fish, *Acanthophthalmus pangia* (Hamilton), living within a short distance of each other in the same stream by the writer (1930*b*) long ago. In one set of specimens, collected from among the debris at the bottom of a pool, the pelvic fins were absent (genus *Apua* Blyth), while in the other set collected from among the pebbles in a swift current, the paired pelvic fins were present (genus *Acanthophthalmus* Blkr.) Those whose interest is to study characters only have already pronounced their judgment by keeping apart the two sets of individuals in two different genera and thereby confusing the issues of evolution. We have seen the same taxonomic treatment accorded to the species of *Nemachilus* that develop a new bladder, though still retaining the old as a vestigeal organ. My knowledge of the environment in both cases is yet too incomplete to explain these adaptations.

Study of environment neglected

Whenever I have studied the taxonomy of a group of fishes, which I have observed alive in nature, it has always been possible for me to understand the functional values of the taxonomic characters, however trivial they may appear in separating species or subspecies. But, though I am trained to describe in the minutest detail the characters of an organism, I am afraid I have always been handicapped in describing the environment in the same detail, for it entails an advanced knowledge of engineering, physics and chemistry. As 'Adaptation' signifies correlation of an animal with its habitat, the study of an animal alone, however detailed, without a similar study of the environment cannot lead to the proper understanding of this universal phenomenon.

For evaluating factors responsible for evolutionary changes, it is thus necessary to know the details of the environment. Though, in a humble way, I have attempted such a study in reference to a few habitats of animals, I am fully conscious that they are very imperfect indeed. As early as December 30, 1928, Dr E J Allen wrote to me in reference to my studies on the torrential fauna already referred to·

> 'The work is very interesting indeed, and the more we can have of the same kind the better. I hope too you will try to start some experimental work, and try and find out "how it is done" It is all very fundamental.'

Only recently, on the 3rd October, 1951, an American friend suggested that it would add significantly to the value of my work if someone could go out in the field and measure water speed to permit correlation of the development of adhesive devices with proportionately faster flow.

Here I must confess that I have never seriously attempted such field studies, which require a detailed knowledge of hydrostatics and hydrodynamics, though only such studies could enable the evaluation of the influence of rapid currents in reference to graded evolution of structures However, Dodds and Hisaw (1924) have discussed the adaptations exhibited by certain Mayfly nymphs of *Baetis* for life in swift currents, and have shown that a direct correlation exists between the swiftness of the current and the degree of reduction of the median caudal seta. *B. tricaudatus*, with 3 tail setae, lives in currents flowing at the rate of 5 feet per second; *B. intermedius*, with a shorter middle seta, lives in waters flowing as fast as 8 feet per second and *B. bicaudatus*, with the middle seta vestigeal, lives in places where the water flows at the rate of 10 feet per second. The reduction of the middle seta ensures proper stream-lining of the body to present a stream-lined form to the swift current.

Difficulties of studying environment biologically

Though a physical scientist may be able to study in detail the physico-chemical factors in an environment, he may not be able to evaluate their biological significance with reference to the fauna under study, unless he is also a trained biologist. The study of adaptations therefore, requires a team-work approach and I think it will be worthwhile to start this work as a co-operative project by biologists and physicists. Whenever I have been able to get the assistance of a physical scientist, the apparent biological riddles have been resolved into simple elementary facts. For example, in Blepharocerid larvae from torrential streams, I was surprised to see that some had long spinous processes on them, while in others the surface was smooth. In ordinary circumstances, the development of spines would be considered not only useless but distinctly harmful to the animal in a rushing torrent Though it seemed to me a paradox, it was shown to me that under certain conditions such processes help to decrease resistance. For instance, it is known to the engineers that 'in some such bodies as spheres and cylinders, the law of resistance may change widely with comparatively small alterations in the conditions; thus, for example, at certain speeds the resistance of a sphere may actually be reduced by roughening the surface' (Gibson, 1923)

I shall refer here to another instance which baffled me for long. Certain Sisorid Catfishes, such as *Conta* Hora, *Glyptothorax* Blyth and *Baguvia* Hora, living in swift-flowing rocky streams have an adhesive apparatus formed of longitudinal folds of skin on the thorax while certain others, such as *Pseudecheneis* Blyth, *Propseudecheneis* Hora and *Parapseudecheneis* Hora, have developed transverse folds in the chest region (Hora, 1952*b*). After considerable study and thought, it became clear that when a cylindrical fish enters swift currents, it will develop longitudinal folds along the ventral surface to increase friction, while a flattened fish will develop transverse folds This view is strengthened by the fact that when the cylindrical fishes, as an adaptation to the ground habit of life on rocks in swift currents, become depressed and flattened and the function of adhesion is passed on to the paired fins, the outer rays become flattened and develop transverse adhesive folds

The above two instances show that a biologist alone cannot properly interpret variations in structures, unless he understands the responsible physical factor or factors in the environment equally well.

Magnitude of adaptive variations

It is now conceded, even by geneticists, that 'adaptation is very unequally distributed through the several taxonomic ranks In general it is considerable in the high ranks, slight or wanting in the low ranks' (Shull, 1951). According to this dictum, the characters that define classes, orders, families and genera have perhaps some adaptive significance, while those characterizing genera, species, and subspecies have rarely any adaptive importance In my opinion, this merely indicates that we understand very little of the unlimited gradations in the environment against which only the minor characters of an animal can be equated I have mostly worked on the taxonomy of hill-stream fishes during the last 32 years and have made extensive collections from all over India myself. I have not only collected fishes from mountain torrents, but have also tried to understand their ways of life through observations and simple experiments carried out in the field. In classifying these fishes right up to the subspecies rank, I can say with a considerable degree of confidence that even the so-called most insignificant characters, such as number and disposition of scales; number of rays in various fins and the shape of fins, nature of the mouth and associated structures, appendages in the axils of fins, etc , etc., have some adaptive significance when considered against the background of environmental factors. For instance, it has been observed over and over again that in fishes that adhere firmly to rocks by applying their ventral surface, the ventral portions of the gill-openings, being non-functional in such circumstances, gradually close up, and ultimately they are greatly reduced and are restricted to the dorsal surface above the pectoral fins. A critic from America has recently written to say that 'This is simply not true. Many Gobies which have adhesive discs and sit on the bottom have terrific gill clefts My guess would be that Hora's fishes have their gill-openings restricted because they are living in such thoroughly oxygenated water and are not active and have, as a consequence, an easy time respirationally'. The adhesive disc of the Gobies is formed by the union of pelvic fins and the ventral surface of the body is, therefore, usually not closely applied to the substratum. Accordingly, in Gobies as a rule, there is no interference with the ventral extensions of the gill-openings But when the Gobioid fishes enter torrential streams and the body becomes greatly flattened, the gill-openings are restricted to the sides and extend to the ventral surface for a short distance only (Hora, 1932*b*).

It is probably true that, when the gill-openings thus become restricted to the dorsal surface in hill-stream fishes, further reduction of their size is due to the highly oxygenated nature of the water. The adaptation that I have not yet been able to account for is the extensive nature of the gill-openings in the Chinese Homalopterid fish *Sinogastromyzon* Fang, in which the ventral surface and the paired fins do form an adhesive disc. Some observations on the respiratory mechanism of this fish will no doubt help in elucidating this adaptation. For the present, it can be included in the list of those adaptations which need to be investigated.

Parallel evolution signifies adaptation

As early as 1922, Annandale and I commented on a remarkable case of parallel evolution in the fish and tadpoles of mountain torrents by referring to the development of a suctorial disc in the fishes of the genus *Garra* Hamilton and tadpoles of *Rana afghana* Gunther. Annandale (1924*a*) again referred to it and, on the basis of my work on *Garra*, pointed out that the different forms found in different types of environment correspond very closely with different stages in the post-larval development of the most highly specialized species. He then predicted that though 'our knowledge of the tadpoles is less complete, the analogy between them and the fish is so close that it is impossible to avoid the conclusion that a similar (but of course not an identical) line of evolution has been followed'. Annandale's prediction came true when I (1932) studied the development and probable evolution of the suctorial disc in the tadpoles of *Rana afghana* Günther. Similarly, in the case of Homalopteroid fishes, I (1932*a*) predicted that forms intermediate between *Vanmanenia* Hora and *Formosania* Oshima still remain to be discovered, and so it was no surprise when Fang described *Praeformosania*. The entire classification of the Homalopteroid fishes is based on adaptive characters and when discoveries of future taxonomic units can be predicted, it seems reasonable to believe that there is some directiveness in evolution.

Taxonomy and adaptations

In 1949, I discussed how a taxonomist assesses a species and how the value of characters may change with individual workers or when more material becomes available. I shall extend this point by referring to the changes that have taken place in recent years in the classification of the Homalopteroid fishes, in which even the minutest characters used for taxonomic purposes can be shown to have some adaptive significance.

In 1920, I published a revision of the Indian Homalopteridae and Day's *Homaloptera* was divided into three genera In 1932, after examining considerable material in European museums, I found that this very characteristic family is polyphyletic and showed on the basis of morphological characters that, whereas *Homaloptera* and its allied forms were derived from the Cyprinidae, *Gastromyzon* and its allied forms have been derived from the Cobitidae. In 1949, I had an opportunity to examine the material of these fishes in the American museums. As a result, the previous view was confirmed and the old Homalopteridae was definitely divided into two families, the Homalopteridae and the Gastromyzonidae (Hora, 1950). Though the material available for study of these fishes is very limited, we have studied them from several aspects, such as cranial osteology (Ramaswami, 1952), structure of scales (Law, 1950), and systematics and zoogeography (Silas, 1952). These studies have shown that the Gastromyzonidae comprise two definite stocks independently evolved from the Cobitidae, the Crossostominae and the Gastromyzoninae. Further, both the Gastromyzoninae and the Crossostominae are independently evolved on the mainland of Asia and in the island of Borneo (Hora, 1952*a*). In each group and in each geographical area, there are several lines of independent evolution showing thereby that the over-riding influence of swift currents has moulded several Cobitid forms independently and have made them converge so as to look superficially alike. For lack of enough material, our investigations into the so-called Homalopteridae of the older writers are not complete though I have been studying this family of fishes for over a generation now. True enough, Darwin enunciated his theory of the *Origin of Species* on the basis of accumulation of a great deal of data, but such encyclopaedic knowledge is perhaps not possible in these days. Now is the age of intensive studies, not of a single order or family but sometimes of a genus from all aspects. Though on account of the time factor, it may not be possible to demonstrate experimentally the role of adaptations in speciation, one will have to turn to the specialists of genera and species to build the edifice of the science of Organic Evolution.

Evolution: divergent and convergent

Both Annandale and I have been greatly impressed by the fact that evolution does not follow a straight course. One notices at every step that to meet the requirements of the environment sometimes the characters converge and sometimes they diverge, but always with the ultimate aim of achieving the same object. In the study of the Homalopterid fishes or the fishes of the Glyptosternoid group of the family Sisoridae, one comes across divergent and convergent evolution in regard to every taxonomic character (Hora and Silas, 1952). The sum total of all the characters constitutes the organism which shows a remarkable adaptation to the environment, whatever may be the line of evolution of each character. The evolution of each character is determined by the initial stage at which it starts so that it acts as mere clay under the pressure of its environment, which moulds it and remoulds it so as to keep it fully adjusted to the requirements of the external condition of its existence.

How do new characters arise

Annandale (1924*a*) thus summarized his views on evolution:

> 'Mendelism is true in some cases; some species produce mutations, but gradual changes also take place under the influence of environment, and are perpetuated. In some circumstances these changes are utilized and become more strongly developed, in some they produce harmless by-products; in others the result is harmful and the race perishes. No one formula can express, much less explain, evolution.'

Since Annandale's time we have observed many more facts concerning adaptations, we are accordingly in a position to take a much bolder stand in evaluating their importance in evolution. Whatever may be the source of variations, Lamarckism, Mendelism, Darwinism, Weismannism, or any other, each variation is subjected to the test of its fitness to the environment if it passes that test it survives, otherwise it is wiped out. The most predominant factor in evolution is adaptation and Dr Cain is, thereby, perfectly justified in cautioning students of evolution 'that those characters or variation patterns that have been described as non-adaptive or random should properly be described as "uninvestigated". One must not assume randomness (or selection) without proof'.

In the evolution and distribution of the hill-stream fishes of south-east Asia, we have now found that the orogenic movements that gave birth to the Himalayas had a great role to play. The movements affected the neighbouring countries and produced many resultant mountain ranges. The streams in the Himalayas and the associated mountain ranges became rejuvenated with each upheaval, thus providing a very favourable stimulus for the production of more and more specialized adaptive fishes As the peninsular region remained more or less stable during these orogenic movements, we did not understand the evolution of new genera of fishes in the Western Ghats having affinities with those found in the Assam Hills, Eastern Himalayas and further east. Now we know that this was made possible by the tilting of the Peninsula by which the Western Ghats was uplifted and the streams in it were rejuvenated (Menon, 1951), thus providing a direct cause for the production of genera like *Bhavania* Hora and *Travancoria* Hora. Hence it will be seen that we require to supplement our biological studies with a knowledge of the palaeogeography of India before we can hope to understand the problems of evolution and distribution of our torrent-inhabiting fishes.

Principles of evolution

In the above account of various aspects of adaptations and their bearing on organic evolution, I have relied mainly on observations I have made myself or of which I have personal knowledge. I am, therefore, in the fortunate position of being able to substantiate each observation with more detailed information It will be seen that the following biological principles can be enunciated for a proper understanding of evolutionary changes in nature:

1. New characters, as a rule, arise as modifications of some pre-existing structures. There is no such thing as the evolution of entirely new characters Thus there is always an organic link between the past and the present
2. The evolution of characters is governed by the innate tendencies of heredity, as well as by the external environmental influences In fact, both Nature and Nurture play a significant part in the make-up of an individual
3. New variations or characters, by whatever means they may arise, are tested for their adaptiveness to the external conditions of the existence of the organism concerned The non-adaptive characters, if harmful to the existence of the organism, disappear or the race perishes In the end, only adaptive characters persist and form the basis of future evolutionary changes It must be remembered that evolution is of the animal through the production of purposeful characters, and not of the characters without any relation to the life of the animal.
4. Evolutionary changes are thus directed towards achieving certain definite objectives. Evolution takes tortuous paths for the attainments of its objectives, for it goes on moulding and re-moulding pre-existing characters to fit them to the needs of environment. This view is amply justified by marked divergences and convergences one comes across in Nature The same objective can be gained by similar organisms by applying different means or conversely by different animals by resorting to similar modifications.
5. Fluctuations in environmental conditions, whether of the gene-complex or of the animal as a whole, are the main sources of variations and thereby of the production of new characters In the case of the hillstream fish-fauna of south-east Asia, the production of new families, genera and species can be correlated with the orogenic movements due to the birth of the Himalayas or other similar violent earth movements. So long as the environment remains static, the organisms do not change very much, but any dynamic environment, such as torrents, marshes, estuaries, shore-line, etc., is an open book for the study of evolution. Palaeogeographical changes have very often converted a static environment into a dynamic one and it is during such periods of the earth's history that vast evolutionary changes have been observed

Conclusion

I believe I have made it sufficiently clear that the study of evolution is in the main a study of adaptations Adaptations resolve themselves into two main lines of investigation the study of the characters of the animals and the study of the environment in which the animal lives The study of characters has advanced to a very high pitch of efficiency, for we are now studying the minute parts of chromosomes and interpreting them in terms of heredity We are, on the other hand, still very ignorant of environment This deficiency is mainly responsible for our quarrels about the theories of evolution and for the inadequate understanding of man and his needs The future lies in ecological studies, whether of organisms or of man So long as we remain ignorant of environmental gradations, it is better to follow Dr Cain's advice and treat apparently non-adaptive character as 'uninvestigated'. This attitude of mind will at least enable the younger generation to investigate nature more thoroughly, and thereby, to cull from it the secrets of evolutionary changes.

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AN ICHTHYOLOGIST LOOKS AT INDIAN PALAEOGEOGRAPHY

S L HORA

(*delivered at Lucknow* 1953)

Today, in India as elsewhere, we are once again inclining towards a unitary view of knowledge: indifferent specialization alone leads away from it. This fact is not just a suitable, perhaps provocative, introduction to an address such as this, for I have experienced its truth deeply in my work. In my principal subject, Ichthyology, for example, I have found that the more intensively I studied it, the more extensive my enquiries and approaches have become. I had to acquire perspectives from other sciences and kindly specialists in other disciplines; I had to find relevant patterns of thought in history and patterns of life in geology; and periodically I had to reassess what I had learned and relate it to the march of science in our country Otherwise, there was no purpose in learning it.

On this anniversary occasion, I am encouraged to offer you another of these syntheses, my purpose this time being to consider some of the paleogeographical problems of India in the light of contemporary information about the evolution and distribution of our fresh water fishes. The major points I shall try to make are that the northern landmass and Gondwanaland were connected by a land bridge in the Assam region until the Middle Eocene; that the Himalayan foredeep of the Miocene-Pliocene period could not have been the Indo-brahm or Siwalik River of the geologists; and that the Garo-Rajmahal Gap became a physiographic feature of India only during the glacial epochs of the Pleistocene I hope that certain other points will also emerge as I proceed.

Freshwater Fishes of the Triassic

Our earliest known freshwater fishes were Dipnoans or Double-Breathers, popularly known as 'Lung-Fishes'. It is characteristic of them that, in addition to having gills for aquatic respiration, their air-bladders are modified to function as lungs for aerial respiration. They have not survived in India, but we find their fossil remains in the Maleri Beds of the Godavari Valley, which are stated to be definitely of the Upper Triassic Period, about 170 million years ago. Their present day discontinuous distribution in Australia, Africa and South America is further evidence of their great antiquity

The Dipnoans are represented in the Indian fossil fauna by the genus *Ceratodus* Agassiz, which had evolved during the early Triassic in the northern landmass and soon became the dominant freshwater fish of the period It is necessary at this stage to have an idea of the geography of the world during the Trias. There was then the Gondwanaland in the south, which, besides Peninsular India, included Australia, Madagascar, the southern parts of Africa, South America and Antartica; and a northern landmass in the north, which included North America, Europe, Siberia, China and Indo-China. These two continental units are believed to have been separated by an east-west running ocean called the Tethys, of which the Mediterranean Sea is now the remnant.

The migration of *Ceratodus* to the Gondwanaland shows that in the Lower Triassic a land bridge had been established, which divided the Tethys Ocean and made it possible for *Ceratodus* to spread all over the Gondwanaland. From India, it wandered to Australia in the Lower Triassic, and continued to live there until the Upper Cretaceous; its fossils are found in Africa from the Lower Triassic to the Upper Cretaceous, but in South America its fossils are known only from the Upper Cretaceous beds.

The genus is now extinct, but a very closely allied form, *Epiceratodus* Teller, is now found in Queensland. During my visit to Australia in 1951, I had several opportunities of seeing this fish and, not finding it coming to the surface, I was surprised to learn that in well-aerated aquaria or ponds, the fish never comes to the surface to breathe. Aerial respiration is resorted to only when the water becomes foul and deficient in oxygen. It has already been recorded by Bridge (1904, p. 510) and Romer (1947, p. 123) that this fish is not capable of burrowing in mud, like the Dipnoan fishes of Africa and South America to which we shall refer presently.

Ceratodus and Climate

The distribution of *Ceratodus* in space and time, and its ecology as inferred from the habits of *Epiceratodus*, give us some clue to the climates of the Triassic Period. There were large rivers, which often flooded the neighbouring areas and filled up extensive perennial depressions. The vegetation, which was carried by floods in the same depressions, was still fairly luxuriant. There must have been dry periods of prolonged duration when the vegetation decomposed and used up dissolved oxygen. These were evidently unfavourable conditions for fishes, but *Ceratodus* could survive them.

In North America, Europe, Africa and Australia, the dry seasons seem to have lasted for longer periods, thus bringing about the fossilization of *Ceratodus* from the Lower Triassic period. India experienced complete desiccation in the Upper Triassic, when the Dipnoan fishes perished; but favourable conditions for their existence seem to have persisted in other areas until the Upper Cretaceous Period. In Queensland, the ecological conditions of the Lower Triassic seem to have continued, more or less unchanged, to the present time, with the result that *Ceratodus* has come to us almost in the same form as *Epiceratodus* in that part of the world.

In Africa, *Ceratodus* seems to have given rise to *Prodopterus* Owen under long-persisting marshy conditions, lasting over millions of years, which probably induced the habit of burrowing in mud and thereby tiding over conditions of drought. This habit led to elongation of the form, degeneration of paired fins, reduction of scales, and so on. In South America, these tendencies seem to have been still further accentuated with the result that *Lepidosiren* Fitzinger is more or less an eel-like fish, capable of aestivating in its underground cocoon for very long periods. That such has been the course of events is further illustrated by the modifications undergone by fishes of the Magur family (Clariidae: Siluroidea) on their arrival in Africa from India during the Pliocene Period, at the most about 10 million years ago.

Freshwater Fishes of the Jurassic

After a period of desiccation during the Upper Triassic, the conditions seem to have become favourable again during the later Triassic; for we find that the Gondwanaland received an invasion of the Ganoid fishes from the north about the end of the Upper Triassic or beginning of the Lower Jurassic Period. Australia appears to have separated from the Gondwanaland at this time, since no Ganoid fish seems to have migrated to Australia. The shrunken Gondwanaland comprised Peninsular India, Madagascar, South Africa and South America.

The remains of the Ganoid genera *Lepidotus* Agassiz, *Tetragonolepis* Brown and *Depedius* Leach are found in the Upper Jurassic Kota Beds of the Godavari Valley. Of these, *Lepidotus* seems to have arrived earlier, for it spread to Madagascar and South America. All the three genera are extinct at present, having died out in the Upper Jurassic. In Madagascar, they became extinct in the Lower Jurassic, while in South America they persisted till the Lower Cretaceous.

Freshwater Fishes of the Cretaceous

By the Lower Cretaceous, favourable ecological conditions for fish life seem to have been established again, when another invasion of Ganoid fishes (*Pycnodus* Agassiz, and *Lepidosteus* Lacépède) took place. *Pycnodus* is extinct at present, but its fossils are known from North America (Lower to Upper Cretaceous), Europe (Lower Cretaceous to Eocene), India (Upper Cretaceous) and Africa (Eocene). *Lepidosteus* appeared somewhat later and is still living in Eastern North America, Central America and Cuba Its invasion of the Gondwanaland extended only as far as India.

Both these genera became extinct in India with the earliest phase of the lava eruptions that formed the Deccan Traps. Their fossils are found in the Upper Cretaceous Lameta Beds at Dongargaon In my opinion, these fishes did not survive long in India and Africa to spread to South America, because some later records of fish distribution show that South America still formed a part of the Gondwanaland during the Upper Cretaceous Their fossil records from India show that trap formation in the Deccan commenced in the upper Cretaceous, and brought about a vast devastation of the fauna and flora.

Freshwater Fishes of the Eocene

After the first phase of the extensive lava flow had ended, normal conditions gradually returned again; and another invasion of the Ganoid fishes of the genus *Lepidosteus* took place early in the Eocene, about 60 million years ago They provide evidence that the Assam land bridge was still in existence, and that Africa and India still formed a part of the truncated Gondwanaland. Another phase of volcanic eruption exterminated the last known Indian Ganoid fishes, their fossil remains from the Inter-trappean beds at Paharsingha and Kateru being described by myself in 1938.

About the same time, some Teleostean fishes also invaded the Gondwanaland from the north. Representatives of one remarkable family, the Osteoglossidae, were described from the Inter-trappean beds of Deothan (Hora, 1938). The now extinct genus *Musperia* Sanders is not only recorded from India, but from the Upper Eocene beds of Sumatra as well; and it is further remarkable that the modern genus *Scleropages* Gunther, an undoubted descendant of *Musperia*, is now found in Thailand, the Indo-Australian Archipelago and Australia.

The palaeogeographic conclusion is that the mainland of Asia at that time was directly connected with Australia, through Sumatra and other islands of the Malay Archipelago Thus, after its severance from the Gondwanaland, Australia became directly connected with the northern landmass, but this connection seems to have lasted only for a short period; for the Acanthopterygian fishes that spread to Africa and South America on the one hand, and to the Indo-Australian Archipelago on the other, do not seem to have reached Australia.

The varieties of Acanthopterygian fishes known from their fossil scales, embedded in the Inter-trappean beds at Deothan, Kheri and Takli, indicate that they lived in marshy, estuarine conditions. Some variety of *Koi Machch* (*Polycanthus* C V.), and allied fishes of the family Nandidae (*Nandus* C.V., and *Pristolepis* Jerdon), formed the bulk of the fish-fauna of that period, which not only spread over the whole of South-East Asia but also entered Africa and South America. Like the Dipnoan and Osteoglossid fishes, the discontinuous distribution of the families Nandidae and Anabantidae shows their great antiquity.

Absence of Freshwater Fishes in the Miocene

Though carps and catfishes dominate the freshwater fish-fauna of India today, and though they had made their appearance on the mainland of Asia during early

Eocene times, the conditions over the Assam land bridge do not seem to have been favourable for their migration to India One fragment (a scale) was doubtfully referred by me (1938, p. 274) to the Ambramidinae, which includes very primitive varieties of the carp family. Some primitive genera of Indian carps are found in Africa too, which adds weight to the probability that the early Eocene fish-fauna of India included *Musperia*, *Polycanthus*, *Nandus*, *Pristolepis* and *Rasbora;* but the eruption of the Deccan Traps during the Lower Eocene seems to have exterminated them completely.

During the Middle Eocene, a transgression of the Bay of Bengal northwards snapped the Assam land bridge and separated India from the rest of Asia The transgression of the sea also made it impossible for freshwater fishes to invade India. The dating of the period of this transgression has been made possible by Sri A G K Menon's recent identification (seen in MS) of a marine Pycnodont Ganoid fish from the Middle Eocene marine deposits of the Garo Hills in Assam.

With the breaking up of the Assam land bridge, freshwater fishes could no longer invade India, while those that had crossed over in the Lower Eocene were exterminated by the successive outbursts of lava Consequently, there was no freshwater fish in India throughout the Miocene period This surmise is supported by the absence of freshwater fish in the Indian deposits of this period

Freshwater Fishes of the Pliocene

The next invasion of freshwater fishes from China to India took place in the Pliocene, as we know from the Siwalik fossils. The earliest fossils are those of the Siluroid (*Magur*) genera *Clarias* Scopoli and *Heterobranchus* Geoffrey. They are specialized air-breathing fishes, which flourish in marshy areas and are capable of tolerating very low salinity. The remains of an Acanthopterian air-breathing fish, *Ophicephalus* Bloch, are also known from the Siwalik deposits, it being presumed that this fish wandered to India along with *Clarias* and *Heterobranchus*. In the Pliocene Siwalik beds, probably of a somewhat later period, are remains of other sluggish-water catfishes of the genera *Chrysichthys* Bleeker, *Mystus* Scopoli and *Rita* Bleeker. Somewhat later still, two other genera of Siluroid fishes, *Bagarius* Bleeker and *Silurus* Linnaeus, probably migrated to India, their remains being entombed in the Siwalik rocks. These fishes live in clear waters at the bases of hills.

The freshwater fishes of the Siwalik Period enumerated above fall into three ecological associations

(1) Air-breathing fishes of marshy areas *Clarias*, *Heterobranchus* and *Ophicephalus*
(2) Fishes of pools, ditches and other sluggish-water areas· *Chrysichthys*, *Mystus* and *Rita*
(3) Fishes of clear, flowing waters *Bagarius* and *Silurus*

It is presumed that the clear water fishes were the last to arrive in India for the following palaeogeographical reasons:

We have noticed that the Bay of Bengal extended northwards to China and Tibet from the Middle Eocene, and that the sea very probably separated India from the rest of Asia during the whole of the Miocene At the close of the Miocene, or early in the Pliocene, the sea would seem to have receded southwards, leaving stretches of low marshy areas extending between China and India. As most of the monsoon winds of that period must have crossed to the north over this marshy area, it can safely be presumed that its ecological conditions during the early Pliocene must have been similar to those of Lower Bengal at the present time.

It was under such conditions that the air-breathing fishes populated this region and spread to India. In fact, *Clarias*, *Heterobranchus* and *Ophicephalus* were able to cross the whole of India and the Middle East to spread as far as Africa. There is abundant evidence from the Siwalik fossils that marshy conditions dominated the early Pliocene along the southern foot of the Himalayas. Gradually, marshy conditions were replaced by drier lands, with pools and ditches, which gave India *Chrysichthus*, *Mystus* and *Rita*. Towards the end of the Pliocene, the low east-westwards hills of the young Himalayas seem to have made their appearance in the region between China and India, thus making the westward dispersal of *Bagarius* and *Silurus* possible. Therefore, during the Pliocene there were three invasions of freshwater fishes, but they only spread along the base of the young Himalayas in the continuous foredeep. They did not move down into Peninsular India.

The Siwalik Foredeep

The location of all the Siwalik freshwater fish fossils between a narrow stretch of the hills between Naini Tal and Jammu raises several points of interest in palaeogeography, and one is almost forced to join in the controversy about the existence or non-existence of an Indo-brahm or Siwalik River at the base of the young Himalayas. Much has been written on this subject without achieving unanimity, so that a zoologist can be forgiven for taking it for granted that the relevant geological evidence is ambiguous. I shall attempt a solution on the evidence of fish distribution.

The location of the Siwalik freshwater fish fossil beds between Ramnagar (near Naini Tal) in the east and Jammu in the west indicates that, in the Siwalik foredeep, a calm zone for sedimentation existed in this region. In fact, Dr M S Krishnan's recent palaeogeographical map, in his contribution to the Rajputana Desert Symposium, published in the first Number of the *Bulletin of the National Institute of Sciences of India*, may be interpreted as showing that the tidal salt water from the west and fresh water from the east mingled in this area, thus producing a dead water zone with no appreciable currents from any direction. Now the question is, when was the foredeep produced? And the answer is that on the fossil evidence it was in existence in the Lower Pliocene. But its earlier existence is not ruled out, for the transgression of the Bay of Bengal since the Middle Eocene permitted no freshwater fauna which could yield fossil evidence for the Miocene epoch.

Geologists tell us that the most violent compressive movements occurred about the Middle or Upper Miocene, when the whole of the marine basin, now the seat of the Himalayas, was raised up into dry land. According to Dr M S Krishnan (1952), 'the compression had also the effect of forming a depression along the front (south) of the Himalayas. This was a long narrow furrow, or a series of furrows, stretching from the north-east corner of India all along the front of Himalaya to Jammu and Potwar Plateau and thence down south to the west of the Indus valley.' From the physiography of the country during the Miocene, it can be reasonably inferred that the greater part of the drainage of northern India was from east to west, and that the furrow referred to above helped to carry the drainage to the west into the sea, even though there was no significant gradient, since the sea then extended over the Assam region as well. 'As compression advanced', says Dr. Krishnan, 'and the mountains in the north steadily increased in height, the shallow depression (technically called the foredeep) at the front became deeper and deeper.' It is thus clear that the foredeep was formed in the Middle Miocene, since the mid-Miocene orogeny was the most violent of all the Himalayan movements.

Numerous streams must have drained into the furrow from the newly formed mountains. During the Murree period (Oligocene—Lower Miocene), the waters in the furrow in the north-west Punjab were brackish, but they gradually reached freshness by the mid-Miocene. There is evidence in the Punjab Himalayas (from the presence of the Murree sandstones) that a furrow may have come into being even in the Oligocene. There are no Murree sediments in the East Punjab and U.P. Himalayas, but the Dagshai and Kasauli beds in the Simla Himalayas seem to have been formed in lagoons.

Upper Tertiary Geography: The Pliocene Furrow

Before proceeding further, let us visualize the geography of northern India at about the close of the Miocene and the commencement of the Pliocene. There was a chain of low hills in the north, with a continuous narrow furrow to the south of them. The Bay of Bengal had receded from the Assam Himalayan region, and marshy areas had been formed in the regions from which the sea had receded. The migration of fishes from east to west shows that even these marshes drained into the furrow.

Thus, though there was no actual river flowing from Assam to the Arabian Sea, there was a furrow that provided westward drainage for the whole of northern India. The waters in this furrow were brackish and tidal as far as Jammu; they were calm and dead as far as Naini Tal; thereafter, to the east, they were fresh and presumably flowing from east to west. Throughout the Pliocene, this furrow formed the repository of everything washed down from the land and the young Himalayas, and these sediments ultimately gave us the Siwalik Hills. Let us now follow up the events after the formation of the Siwalik Hills in the late Pliocene.

The Pleistocene Foredeep

Dr Krishnan (1952, p. 46) tells us that, after the Middle or Upper Miocene phase of compression, 'the next two phases of the compression occurred at the end of the Pliocene period and during the Pleistocene to Sub-Recent period. The Pleistocene movement was particularly intense in the north-western Himalayas, as they brought about the rise of the Pir Panjal Range.' Dr D N Wadia (1952, p. 14) is also emphatic on this point, for he says that 'It is a well-documented fact that the Himalaya Mountains have been elevated more than five thousand feet since the coming of Man on earth, itself the last great event in our Planet's history'.

The result of the compression movement of the late Pliocene, and the subsequent Pleistocene movements, raised up the Siwalik sediments into dry land; and the foredeep gradually disappeared, leaving a shallow depression in which we find the Indo-Ganges-Brahmaputra Valleys of the present day. The foredeep apparently moved southward, as the shallowing process went on leaving a narrow furrow at the base of the Siwaliks. This new foredeep, which for convenience we can call the Pleistocene Foredeep, must have taken up the function draining northern India to the Arabian Sea.

By this time, the Assam plateau had come into existence, and so the foredeep could flow as a river from east to west: its remnant is the Indo-Gangetic Plain of our contemporary geography. In some places, the alluvium is surmised to be as deep as 18,000 feet, and below the alluvium the rock probably has the consistency of the rocks of the Siwalik Hills.

Thus, it would appear that a part of the Pliocene Foredeep also became a part of the Pleistocene Foredeep. Early in the Pleistocene, but not the Pliocene, we had an Indo-Brahm River, which played a great part in bringing about uniformity in the Indo-Gangetic fish fauna; for it was during the Pleistocene that the greater part of the recent freshwater fish fauna of India entered the country The present-day drainage of northern India resulted from the last phase of compression, which occurred in the Sub-Recent period.

Therefore, the dismemberment of the Indo-Brahm took place in the very late Pleistocene, but before the fourth and fifth phases of glaciation, as is evident from the spreading of the Gangetic fauna to the Mahanadi and Godavari Rivers only when the sea-level was much lower than it is at present.

This dismemberment enabled the Ganges and the Brahmaputra to find easy access to the sea through the Garo-Rajmahal Gap, which would appear to have been in existence before that period

The Gap is so important a feature of the physiography of India from the view-point of fish distribution, that I shall now turn to discussing it.

The Garo-Rajmahal Gap

When the idea that the Vindhya-Satpura trend of mountains served as the main route of migration for the torrential fishes occurred to me in 1937, the Garo-Rajmahal Gap assumed special importance for biogeographical studies. Later, much evidence in favour of the Satpura Hypothesis of dispersal became available, and I (1944) provoked a discussion by writing an article on the probable age of the Gap. Several geologists took part in the discussion, but the position remained ambiguous In 1949, in the Symposium on the Satpura Hypothesis, the Gap received considerable attention, but there remained the same ambiguity.

Other ecological factors have since been found (Hora 1951) that permitted trans-gap dispersal of torrential animals, but the fact remains that the Gap seems to have acted as a barrier to fish dispersal during certain periods. Its chronology and physiography are accordingly of vital importance in the study of freshwater fish distribution in India Therefore, we are greatly indebted to Dr M S Krishnan (1952, p. 47) for clarifying the sequence of events which led to the formation of the Gap. He writes:

> 'In the early part of the Tertiary era, the Assam plateau did not exist and the area now occupied by it was under the sea, for we find strata of Eocene age along the southern margin of the plateau. The plateau seems to have been uplifted to the present position in the Miocene period. There is also some evidence that a series of uplifts took place in Chota Nagpur plateau during the Tertiary era. It seems likely that some weakness developed in the region between the Rajmahal hills and the Garo hills during the period of uplift of the Assam plateau, for we know that the northern margin of the plateau is marked by a rift or fracture (called a 'fault' by geologists), while the southern margin is a steeply dipping arm of a flexure or fold which plunges down into the Surma Valley The Garo-Rajmahal Gap may therefore have been formed either during the Miocence period of compression or later.'

According to Dr Krishnan's maps of the land and sea boundaries of India during certain geological epochs, it would appear that the Assam plateau began to make its appearance in the Miocene, for during that period the land and sea boundary in the region of Shillong would appear to be more or less the same as during the Eocene The fault that produced the Gap may have occurred when the area was covered by the sea, for even the Pliocene map of Dr Krishnan still shows it under the sea As we have no fossil evidence of any fish dispersal to Peninsular India during the Pliocene, Dr Krishnan's map must be regarded as correctly representing the land and sea boundaries over this region.

It should be added that, though the actual fault may have been either of Miocene or Pliocene age, the Garo-Rajmahal Gap seems to have taken its present form as a physiographic feature of India during the Pleistocene It was only during the late Pleistocene that the Ganges and the Brahmaputra river-systems appeared as we know them today, and found their way to the sea through the Gap.

I have tried to show how, with the formation of the Himalayas and the Pleistocene Foredeep, freshwater fishes from the north-east colonised northern India. We shall now see how, with the Garo-Rajmahal area becoming dry land, the movements of fishes from the north-east were facilitated to Peninsular India. In any case, the present-day freshwater fish fauna of the Peninsula is not older than the Pleistocene.

Freshwater Fishes of the Peninsula Today

We have seen that so long as the Assam land bridge between India and south-west

China was in existence, Peninsular India was invaded several times by freshwater fishes from the north-east: Dipnoans during the Triassic; Ganoids during the Jurassic and Cretaceous; and Ganoids and Teleosteans during the Eocene. The fishes of the first two invasions died out completely owing to desiccation, while those of the later invasions were completely annihilated by the formation of the Deccan Traps Moreover, with the breaking up of the Assam land bridge by the transgression of the Bay of Bengal during the Middle Eocene, no more freshwater fishes seem to have invaded this part of India until the Pleistocene period. There are no fossil records of freshwater fishes from Peninsular India after the Lower Eocene

We have also seen that, with the formation of the young Himalayas, northern India began to receive freshwater fishes from China during the Pliocene. Their fossils in the Siwalik beds provide ample testimony to this effect. Peninsular India, on the other hand, received its fish fauna after the area covered by the Garo-Rajmahal Gap had become dry land during the Pleistocene. The periodicity of migration across the Gap was determined by the eustatic movements of the sea during the glacial epochs.

After the dismemberment of the Indobrahm during the last glaciations, when the sea-level was a few hundred feet lower than it is now, the waters of the Ganges and Mahanadi probably formed a common delta permitting the mingling of the fauna The fauna that had migrated to the Western Ghats along the Satpura trend of mountains, during the successive glacial periods, had the opportunity of spreading eastwards, and to the north of the Vindhya-Satpuras, when the tilting of the Peninsula occurred during the late Pleistocene.

All these aspects have been studied recently by my colleagues and myself (Hora, 1951; Menon, 1951; Silas, 1952; Hora, 1952, *in press*), and those who are interested in the Pleistocene geography of India should, I believe, find information of some value in these contributions. We have established, on the evidence of fish distribution and speciation through isolation and the dynamics of environmental changes, that the following geographical phenomena took place during the Pleistocene:

(1) The Garo-Rajmahal Gap appeared as a physiographic feature of India in the Pleistocene, as a result of the Pliocene-Pleistocene phase of compression of the Himalayas; or it may have appeared as dry land during the earlier glacial periods of the Pleistocene.

(2) In the foredeep of the rising Himalayas, there flowed a freshwater Pleistocene river, the Indobrahm, from Assam to the Arabian Sea.

(3) Through eustatic movements of the sea during the glaciation phases, movements of fishes could take place across the Garo-Rajmahal Gap; and it is probable that freshwater fishes migrated to Peninsular India only during these favourable phases

(4) The tilting of the Peninsula occurred during the late Pleistocene, and it was only then that its present-day west to east drainage was established Before the tilt, there was an east to west Narbada-Tapti River, flowing at the base of the Satpura, into which drained the Mahanadi and the Godavari Rivers flowing north-westwards

(5) During the last glacial phases, after the tilt and the dismemberment of the Pleistocene Indobrahm, both of which may be the results of identical forces, the Ganges and the Mahanadi formed a common delta. Some contemporary tributaries of the Godavari may then have drained into the Mahanadi

These are our principal conclusions We feel they are of some importance to the development of Asian biology, and I have hoped to show in this address that geologists and geographers can use them as indicators for a fuller understanding of the palaeogeography of our country Moreover, as I hinted to begin with, there is a larger purpose—perhaps you can call it a philosophical purpose—behind the correlative ideas I have had the honour of placing before you. It is the purpose of closer liaison between those of us who seem to be working at very different branches of knowledge, but whose results merge into a unity. Sometimes we are inclined to lose sight of this unity, to think that specialization is a narrowing down of one's interests rather than a means of en-

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larging the unity of knowledge by intensive studies; and if what I have said this afternoon, and elsewhere, helps to bring about a reorientation of scientific approaches in India I shall feel amply rewarded. The patience with which you have listened to me suggests that this point of view appeals to you, and I thank you very sincerely for your encouragement.

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I

PROFESSOR KARIAMANIKKAM SRINIVASA KRISHNAN, FNA*

(Foundation Fellow; President, 1953-54)

Professor K S Krishnan was born on December 4, 1898 in Watrap, Distt Tirunelveli (now Ramnad) of Tamilnadu He was the Professor of Physics at Indian Association for the Cultivation of Science and University of Allahabad and later served as the Director, National Physical Laboratory He was the President, National Academy of Sciences; Fellow, the Royal Society, London (1940), General President, Indian Science Congress (1940), Chairman, Scientific Advisory Committee, UNESCO, Vice President, International Council of Scientific Unions; Chairman, Board of Research in Nuclear Science, Member, Atomic Energy Commission, Board of Engineering Research, Standing Board of Astronomy, the University Grants Commission and Founder Member of International Union of Crystallography He was elected as Foreign Associate of US National Academy of Sciences He was the recipient of Padma Bhushan (1954) and the first recipient of S S Bhatnagar Memorial Award in 1961. He was made a National Professor by the Government of India.

Professor Krishnan studied magnetic properties of crystals in relation to their structure; he was able to correlate the anisotropy of crystals with the anisotropy and arrangement of the individual molecules or ionic groups He also studied classical scattering of light, X-rays and electrons; quantum theory, wave mechanism and statistical thermodynamics.

PRESIDENTIAL ADDRESS

KS Krishnan

(delivered at Hyderabad, 1953)

Dr. Krishnan in his presidential address, spoke on some recent development in thermionics, *i e*, the emission of electrons from hot bodies, which formed, ultimately, the basis for the working of radio valves, and of many modern electronic instruments.

Dr. Krishnan said "A thin filament of tungsten or other suitable material, which can be heated inside a vacuum tube, forms the source of electrons, and they are collected in a positively charged electrode This corresponds to the passage of an electric current Such a current can be controlled and manipulated with ease, with the help of auxiliary electrodes and hence serve a variety of purposes. This explains the ubiquitous part played by such electronic tubes in modern instruments A knowledge of the emission characteristics of these heated filaments, which serve as cathodes in the vacuum tubes, is, therefore, of fundamental importance

"Now, the electrons in a metal are capable of migrating more or less freely over the whole of the metal, but cannot normally leave the metal, since the surface acts as a barrier In order to be able to leave the metal, the electrons have to climb over the barrier, and have, therefore to have the requisite energy. This is supplied by heating the filament to a high temperature The emission of the electrons from the hot filaments thus resembles in some ways, the evaporation from the surface of a liquid. Such molecules as have the requisite energy can cross the barrier into the vapour state.

"Hence, the thermionic properties of a metal, which usually are investigated through a study of the characteristic of emission from the surface of the hot metal, can be investigated even more conveniently by studying the saturation vapour pressure of the electron gas in thermal equilibrium with the metal at different high temperatures. The method bears a close analogy to the method of determining the latent heat of evaporation of a substance by studying its saturation vapour pressures

"Such a method has recently been developed in the National Physical Laboratory of India The method can give a precise measure not only of the magnitude of the energy barrier at the surface, but also of the small variation of this energy with temperature, which also plays an important part in determining the characteristics of the actual emission from the hot surface Many metals and alloys that cannot be studied by the usual methods based on actual emission from the surface, can be studied by the new method and they yield interesting results They throw considerable light on the detailed energy structure of the electrons inside the metal. This is particularly the case with what are called the transition elements in the periodic table, like iron, cobalt and nickel, or platinum and palladium, in which there is a considerable overlap of some of the electronic shells.

"The method completely eliminates the rather complicated and very uncertain part played by the presence of thin surface films of absorbed gases on the metal, which are quite unavoidable in the usual method. Further, it also throws light on the precise part played by these films These form the subject-matter of a series of papers published in the *Proceedings of the Royal Society*.

"Incidentally, it may be mentioned that

the simple problem of determining the temperature distribution along a thin filament heated *in vacuo*, which is of great importance in the design of sealed-in heating elements, such as are used in thermionic and other tubes, has presented some serious difficulty. Though the integral defining the temperature distribution can be readily formulated, the evaluation of the integral could only be done till now either graphically or with the help of the calculating machine.

"It has been shown recently that the integral may be evaluated in the form of a simple power series which is rapidly convergent and many interesting results regarding the temperature distribution follow naturally from the evaluation of the integral.

"The effect of this known temperature distribution on the emission from different parts of the heated filament, is also of great practical interest "

DR AMULYA C UKIL, FNA*

(*Foundation Fellow, President, 1955-56*)

Dr A C Ukil was born in November 1888 at Bangaon in Distt Jessore (now in Bangla Desh). He graduated with a Medical degree from University of Calcutta (1914) He was the Professor of Bacteriology, National Medical Instt , Calcutta; Physician-in-charge, Chest Department and Principal, Calcutta Medical College and associated hospitals (resigned in 1948) and later became consulting physician, Chest Department, Calcutta Medical College Hospital (till 1963) He was the Chairman, Bengal Tuberculosis Association (1948), President, All India Tuberculosis Workers' Conference; Member, Council of Indian Institute of Science Bangalore, Scientists Panel, Indian National Planning Commission; President, Indian Medical Association (1955-56) and Asiatic Society (1956); Sheriff of Calcutta (1955-56) and President, Indian Science News Association He was a Fellow of the Royal Society of Tropical Medicine and Hygiene, London; a Fellow of the Royal Sanitary Institute, London; a Corresponding Member of the Society of Tropical Pathology, Paris and a member of the Central Committee on Tuberculosis in Germany

Dr Ukil will always be remembered for his pioneering work on tuberculosis in India. One pathogenic anaerobic bacillus has been named *Bacillus ukili* after him.

THE FRONTIERS OF MEDICINE

A C Ukil

(delivered at Agra, 1956)

Introduction

From the earliest times man has been actuated by the instinct of self-preservation and the natural impulse of life-interest and life-protection. The need for safeguarding life and health arose out of these considerations. The science of medicine began mostly on the basis of observations and speculations based on them.

The available literature shows that, between 600 BC and AD 200, considerable progress was made in India in anatomy, major and minor surgery, internal medicine and pathology, midwifery and children's diseases, hygiene, toxicology, *elixir* (? internal secretions) and sex hygiene. Hospital services, both for men and animals, existed, and nursing services were utilized. There were excellent rules of personal hygiene and some of community hygiene

Gradually, the balmy days of this civilization receded and the Indian savants became speculative and bound by tradition The period between the second and fifteenth century AD was a dark period for the science of medicine, more particularly in Europe. Modern science began to emerge in Europe in the sixteenth century. Subsequent scientific discoveries in physics, chemistry and other exact sciences had their impact on the medical science, which became steadily progressive since the eighties of the last century. Fifty years of the twentieth century saw enormous advances in all sciences and these had their impact on the science of medicine.

The Body-mind of Man

Medical science includes both science of the *body*—its growth, structure and functions, as also their variations and derangement, besides ecology, and of the *mind*—its normal and abnormal behaviour under conditions of stress and strain in modern life The development and maintenance of normal health and the treatment of diseases are also within its domain Medicine is in reality one of the branches of biology and just as biology, in general, needs a foundation on the basic sciences of chemistry, physics and mathematics, so does also the science of medicine which is, for the greater part, applied biology

Natural sciences deal with things and with beings, but the human body, in particular, is endowed with the mind complex and human behaviour, including emotional aspects, which is conditioned by social changes and human relations at home, at work and in the environment. The study of sociology and psychology helps us to determine the patterns and alterations of human behaviour normally and in times of stress and strain which may affect physical health. Because of man being a biological creature, the study of sociology has assumed importance Medicine, in this sense, may be considered as a social science

Social forces are gradually impinging upon medicine to an increasing extent with increasing industrialization and its complexities The study of occupational hazards needs the help of physics, chemistry and toxicology. Social psychiatry, which is gradually developing into a science, deals with two interrelated aspects—the influence of society on the origin of mental illness and its treatment and prevention, and the influence of psychiatry on society.

The Physical Basis of Life

We can now study life from the point of view of phenomena observed in physics, chemistry and biology. J Perret (*New*

Biology, 1952, **12**, 79) defines life, as follows:—'Life is a potentially self-perpetuating open system of linked organic reactions, catalized step-wise and almost isothermically by complex and specific organic catalysts which are themselves produced by the system.' Many scientific workers, notably Huxley, Haldane, Engels, Pirie and Bernal, believe that organic life has evolved from inorganic origins Proteins are the essential basis for carrying out the processes one calls "life". In fact, Engels referred to life as 'the mode of action of albuminous or protein substances'.

According to Bernal (1951), living organisms are composed of large numbers of complex chemical molecules, which consist mostly of simple molecules, like amino-acids, purines, sugars and phosphoric acid, out of which are formed the more complicated macro-molecules of the proteins and nucleic acids and microscopically visible structures like membranes and fibres. Tracer studies indicate the existence of intermediate molecules.

In terms of biological energetics, 'life is a dynamic equilibrium in a polyphasic system'. In living cells, both anabolism and katabolism proceed together and energy drawn from katabolic processes is used in anabolism. A part of the total potential energy is available for the performance of work. The primary function of protein food is to supply the amino-acids required for the growth, repair and maintenance of the structural and catalytic machinery of living cells.

Physical science helps us to understand biology in terms of the theory of solids and liquids. The development of new physical tools and the quantum theory have helped us to understand enzyme-promoted energy changes in chemical reactions and the phenomena of the growth and assimilation of living tissues.

In the sphere of both structure and energy change, new physical and chemical instruments are offering the biologist unprecedented opportunities for study. The introduction of radioactive tracers is unfolding many reactions in both organic and biochemistry. For the determination of molecular structure, the use of spectroscopy (particularly infra-red spectroscopy) and of crystallography is being made. Differential chromatography, which helps to analyse the simple and complex constituents of proteins and other organic substances, provides a bridge between the chemistry and physics of large molecules. Physico-chemical methods have clarified the structure of molecules and a much deeper understanding of the structure and function of the cell containing the nucleus and cytoplasm has been obtained with the help of physical and chemical methods, such as the electron microscope and X-ray researches.

Until the advent of the electron microscopy, a great gap existed between the knowledge of atomic combinations provided by chemistry and that of histological structures possible to be seen through the microscope. With its help, the so-called 'colloid' world is unfolding itself for inspection and precision study. The electron microscope is also indicating the continuity between the external structure of protein molecules and viruses. The results of polarized light and X-ray diffraction studies are in satisfactory agreement with the electron microscopical findings. The ultra-violet, infra-red, polarizing, reflecting and phase microscopes are being utilized for further knowledge about many problems. It is hoped that all these technical advances will speed up the *tempo* and extent of biological researches.

The chromosomes are important components of cells because they carry genes, the physical units of heredity which determine the morphological and behaviour pattern of the organism. The chromosomes are the essential elements of heredity, variation and evolution. Changes of many types occur in the chromosomes, which are either natural events or experimentally induced effects. The study of these phenomena has enriched fundamental knowledge and now provides the basis by which the behaviour and organization of the chromosomes may be controlled. The experimentally induced criteria by which the biological efficiency of ionizing radiations is measured and the impact of chemical agents upon intracellular systems are revealed. The more recent advances in radio-chemistry have made it possible to study the factors of chromosome breakage

For a little more than a decade, a most powerful new tool has been placed in the hands of biologists For most biological investigations, the isotopic tracer method has many advantages over the classical methods of biochemistry It is much more sensitive than the most refined ordinary chemical methods Radioisotopes enable us to 'tag' or 'label' elements in the living organism or its environment and to detect and measure them without disturbing the equilibria under study The method also helps us to solve problems concerning the distribution and fate of elements and compounds in the body which are normally present in quantities too small for satisfactory chemical determination As one can detect extremely small quantities of radio-isotopes by suitable methods, it helps us to detect them in the intact and living organism without the necessity of taking samples About some of its applications in medicine we shall talk later on

The Contribution of other Sciences to Medicine

While methods in biology, physics and chemistry have considerably helped in understanding the human body in health and disease, studies in *sociology and psychology* have helped in understanding the social relations of medicine.

Chemistry has contributed considerably to medicine. In addition to understanding the structure and property of substances which occur in the body and take part in metabolic processes—fats, carbohydrates, proteins and their intermediate products, it deals with the composition of drugs and substances used as therapeutic agents. The recent chemotherapeutic discoveries may be considered as landmarks of achievement Chemistry is also indispensable for determining the pharmacological basis of therapeutics. A landmark in biochemistry is the working out of the complete chemical structure of the insulin molecule (a protein) and of hormones and enzymes Another landmark is the working out of the structure of ACTH, adrenocorticotropic hormone, by which the adrenal glands are stimulated to activity Other hormones have similarly been synthesized, applying methods in physical science, organic chemistry and biochemistry—thus enlarging the limited divisions of these sciences

A muscle is a physico-chemical system operating at constant temperature and pressure The study of contractile mechanism and muscle behaviour needs the application of thermodynamic procedures A study of muscle physiology needs the application of both physics and biochemistry Biomechanics is being utilized in the study of skeletal (such as fractures) and muscular systems.

The applications of *physics* in medicine have been so diverse and so numerous that a vast subject of Medical Physics has developed within recent years This has developed as a co-ordinated subject embracing physics, physical chemistry and biology Physical phenomena have helped to understand the physiological processes in medicine, such as viscosity, surface tension, adsorption, optics, auditory organ and acoustics, photography, spectroscopy, spectrophotography, radiology and radiotherapy, physiotherapy, hydro-dynamics and electrical conduction of the human body. Electrical phenomena of cells, tissues and organisms now constitute an important part of the biological and medical sciences. These are being gradually analysed by the more advanced and powerful techniques of the physical sciences.

The structure and properties of surfaces and membranes have helped us to understand cellular permeability and its variations under stress and stimuli, including the phenomena of osmosis and phagocytosis. Physical methods have also helped us to estimate the surface energy per unit area (=ergs per sq metre).

Modern cardiology needs a knowledge of radiology, electrocardiography and a study of the circulation by radioactive isotopes Electro-encephalography attempts to map out the structure and function of the brain The use of artificially produced *radioactive isotopes* has opened up a large and fertile field for medical research, diagnosis and therapy. By this method, investigations have already been carried out regarding metabolism (nuclear, thyroid, plasma protein, collagen, synthesis of fat and of certain amino-acids from ammonium citrate, cholesterol, carbon dioxide exchanges, porphyrin, etc), measurement of effective circulation in a particular time, measurement of blood-cell and blood-volume, localization of brain tumours and lactating breast tumours, treatment of thyrotoxicosis with radioactive iodine, radioactive ^{24}Na and ^{82}Br in the treatment of carcinoma of the bladder, etc

Isotopic tracer method has also been used in the field of immunochemistry. Satisfactory methods have now been developed for labelling antigens and antibodies with such isotopes as ^{131}I, ^{35}S, ^{13}N, and ^{14}C without seriously altering their immunological characteristics, thus facilitating our knowledge about the site of antibody formation. Labelled antigens have been used in the study of many types of allergy. These methods may prove useful in the study of blood-group agglutinins and the role of lipids in serological reactions and in antibody formation in the animal.

In epidemiological investigations on infections, insect vectors and carriers of infection can be 'branded' with isotopes and the radioactive infective agents and insects can be followed up as regards transmission and habits Identification and localization of radioactive materials by autoradiography have helped histochemical techniques. Histochemical techniques have now been employed in the field of parasitology to study the cytochemical make-up of certain protozoal and helminthic parasites.

The development of *electronics* has led to the manufacture of electronic instruments which are being increasingly used in the diagnosis and treatment of diseases.

Man's work and living in the modern *industrial* civilization expose him to various physical *hazards*, such as electromagnetic and particulate radiations, abnormalities of air pressure, abnormalities of temperature and humidity, abnormal illumination and noise, acceleration, etc Their study and control require the collaboration of physiologists, physicists and chemists.

Aviation medicine deals with man's reaction to the physical variables of air density, environmental temperature, accelerative forces and the time of exposure in aircraft environment The recent introduction of rocket-driven aircraft brings in the study of engineering possibility of human flight under conditions of extremely low air density, oven-like cockpit temperature and extremely high accelerative forces. Aviation medicine thus brings in questions of physiology, biophysics, biochemistry, engineering, anthropology and psychology.

An adequate way of expressing the quantitative character of physics is by the use of *mathematics* Biometry or quantitative biology deals with the statistical study of biological problems So a good knowledge of mathematics has to be acquired by a medical research aspirant.

Collaboration between different Scientific Fields

In the preceding paragraphs, I have already referred to some fields where a fruitful collaboration has been achieved. Examples given in the following paragraphs are rather illustrative than exhaustive.

In the field of *pharmacology*, if one wants to study the metabolism, absorption, excretion and tissue distribution of a certain chemotherapeutic drug, one can administer it containing a labelled atom and then trace out the drug and its metabolites by autoradiographic techniques along with chromatographic methods and thus find out the sites where breakdown of the drug occurs Here, synthesis of the radioactive drug is the job of the synthetic chemist, while the remaining tasks belong to the biochemist, pharmacologist and biophysicist. Biology and biochemistry have shared great benefits as a result of development of biophysics.

In the field of *insect biochemistry*, it has been found that certain flies and mosquitoes subjected to repeated DDT treatment tend to become resistant to it Recent paper chromatographic studies, coupled with radioactive tracer technique, have shown that the resistant fly is capable of transforming the absorbed DDT to a non-toxic ethylene derivative, probably by enzyme action. In this line of study, joint collaborative work in biochemistry, chemistry, entomology and biophysics is needed.

The use of radiophosphorus for the *measurement of blood-volume* and the use of radiocobalt for the *treatment of cancer* constitute an example indicating joint collaboration between clinical medicine and biophysics

Backwardness of Medical Research

It has been a matter of concern for the organizers of scientific research in India, that biological and medical research have somewhat lagged behind, compared to that in the physical sciences In order to make up for this deficiency, the CSIR, under the Ministry of NR and SR has appointed a Committee for sponsoring research in these fields.

Medical research in India has been backward for various reasons. In undergraduate medical education, interrelations of the various sciences which have enriched medical science are hardly emphasized. Most medical colleges are ill-equipped and understaffed, while clinicians care more for patients and prescription-writing than for researches into the unsolved problems of medicine In fact, a research atmosphere does not prevail in most of the medical colleges.

Very few of the medical research centres in India are equipped with modern scientific tools or have scientists of other disciplines on the staff with whom collaborative work can be pursued The universities, being mostly poor and apathetic, do not extend as much supervision and offer as much co-operation as in the other fields of study Finally, the people and the administrators are not yet sufficiently research-conscious to offer encouragement and provide funds

Need for Co-ordinated Research

From what has been stated above, it will be realized that the Frontiers of Medicine are being constantly widened by the impact of researches in other fields and that co-operation between the different branches of modern science, such as chemistry, physics and mathematics, is necessary for knowledge and advanced study of the subjects The collaboration of the clinician with the anatomist, physiologist, chemist, medical physicist, pathologist and statistician may help in solving scientific problems by the co-operation and exchange of modern knowledge between different scientific fields At least one-third of the researches undertaken should be of a fundamental nature. Medical scientific problems must be solved by a team of scientists, each an expert in his own line

I realized the truth of the above position in the course of my work on microbiology, pathology, epidemiology, climatology and the effect of solar radiation on human beings and inoculated animals, when I had to take the help of clinicians, chemists, physicists, meteorologists, epidemiologists and statisticians, but, in each case, I had to waste considerable time and energy in inducing them to collaborate with me. If there were arrangements for team work in the same institution, a sizable portion of my time could have been diverted to other fruitful channels.

I take this opportunity of making a fervent plea for reorganizing medical research in India with its base at the universities and the university medical colleges and its peak at specially organized research institutions to solve specific medical or health problems, with arrangements for collaborative work at every level and co-ordination between the interrelated departments of the Union and State Governments, the University Grants Commission and the different Councils of Research under the various Ministries. There should also be close co-operation between medical research and research in the fields of industry If these suggestions are accepted, medical research in India is likely to increase both in *tempo* and volume.

PROFESSOR PRASANTA CHANDRA MAHALANOBIS, FNA*

(*Foundation Fellow; President, 1957-58*)

Professor P C Mahalanobis was born in Calcutta on June 29, 1893 He did his post-graduation from University of Cambridge, UK where he took part I of the Mathematics Tripos and part II of Physics Tripos. He joined Indian Education Service in 1915 and became Professor of Physics at Presidency College from where he retired as Principal in 1948. He was the Chief Executive since founding of the Institute in 1931, Secretary and Director of the Indian Statistical Institute, Calcutta, Honorary Statistical Adviser to the Government of India since 1949; Member, Planning Commission (1953-67); General Secretary of the Vishva Bharati (1921-31), Head, Statistics Department, University of Calcutta (1941-45) He was the Member of UN Statistical Commission since 1946 and its Chairman (1954-58); President, Indian Science Congress (1950); Fellow, the Royal Society of London (1945), the Econometric Society, USA (1951), the Pakistan Statistical Association (1952), Honorary Fellow of the Royal Statistical Society, UK (1954) and King's College, Cambridge (1959); Honorary President of the International Statistical Institute (1957); Foreign Member of the USSR Academy of Sciences (1958), Fellow of the American Statistical Association (1961) and Fellow Member of the World Academy of Arts and Science (1963) He received the Weldon Medal from Oxford University (1944), Gold Medal of the Czechoslovak Academy of Sciences (1963) on his seventieth birthday, the Sir Deviprasad Sarvadhikari Gold Medal (1957), Durgaprasad Khaitan Gold Medal (1961) and the Srinivasa Ramanujan Gold Medal (1968) He received Honorary Doctorate from Calcutta, Delhi, Stockholm and Sofia Universities

The Indian Statistical Institute was founded by him in 1931 The estimation of acreage and crop yield by random sampling, national sample, surveys for collecting socio-economic data, consumer expenditure, public opinion, etc were done by him. Much pioneering work was done in the design of sample surveys; organisation of field work and tabulation of records for which Professor Mahalanobis as well as ISI received wide recognition. 'Mahalanobis distance' is widely used in taxonomical classifications.

SCIENCE AND NATIONAL PLANNING

P C MAHALANOBIS

(delivered at Madras, 1958)

Introduction

In recent years the Anniversary Meeting is being held separately from the Annual Meeting, and the tradition has been for the President to select a subject for the Anniversary Address from some branch of science of which he is a student and give a general review acceptable to other scientists As I cannot claim to have specialized knowledge of any particular subject, I looked at the Presidential Addresses of some of my distinguished predecessors for guidance. From the inauguration of the Institute in 1935 I found a continuing concern with problems of organization of scientific research in India The functions and responsibilities of the National Institute of Sciences have also been reviewed a number of times. Looking back I had the feeling that many of the problems are still with us in one form or another.

In 1938, exactly 20 years ago, Meghnad Saha selected for the Presidential Address the "Problem of Indian Rivers," and pleaded for the initiation of systematic studies to lay a scientific foundation for flood control, irrigation, and navigation He also gave a full discussion of benefits which would accrue by generation of cheap electrical power out of the energy of running water. He had mentioned at that time: "This is a subject which is just beginning in India but its importance has not been properly realized." He referred to poverty and unemployment; and asserted that "industrialization (was) the only solution of the poverty problem." He also referred to planning in Russia, and pointed out that "when the Supreme Council of the Soviet adopted Lenin's resolution for the electrification of the country, it was the USSR Academy of Sciences, and not a committee of bureaucrats which was requested to give a plan " He concluded his Address with the following words:

> 'If we desire to fight successfully the scourge of poverty and want from which 90 percent of our countrymen are suffering, and lay the foundation of a strong and progressive national life, we must make the fullest use of the power which a knowledge of Nature has given us We must rebuild our economic system by utilizing the resources of our land, harnessing the energy of our rivers, prospecting for the riches hidden under the bowels of the earth, reclaiming deserts and swamps, conquering the barriers of distance and above all, we must mould anew the nature of man in both individual and social aspects, so that a richer, more harmonious and happier race may live in this great and ancient land of ours "

The picture in the mind of the scientist twenty years ago has already become real in the great river valley schemes of India This is the task of the scientists, to formulate the shape of things to come, not as wishful thinking but based on the knowledge of Nature and worked out in accordance with the methods of science The two basic problems, poverty and unemployment, mentioned by Saha still remain as acute as ever The only way out is through rapid industrial development based on science and planning I feel this is an appropriate subject for my Address.

"Sputnik"

On the 4th of October, 1957, an artificial satellite "Sputnik" was launched by USSR followed in a month's time by a second and bigger one carrying a live dog We received this news when our Council was in session; and on the 6th October, at the desire of the Fellows of the Institute assembled at the Annual Meeting, we sent a message of congratulation to the USSR Academy of Sciences.

The way to outer space beyond the

earth's atmosphere was thus opened for the first time. It is a great triumph of science. Epochs of history can no longer be demarcated in terms of dynasties or of war between nations but must be thought of in terms of the progress of science and technology

The upsurge of science in what we call the West (that is, in the countries of Europe and North America) led to the industrial revolution characterized by the use of machinery driven by steam, and later by electricity, for the production of goods, and brought about a rapidly increasing level of living in the industrially advanced countries during the last 100 or 150 years. This increase in industrial production gave the West its superiority in armaments; and brought practically the whole world under its domination. Striking developments occurred during the last fifteen years Atomic energy (for bombs and for electricity), high-speed rockets, guided missiles and satellites have been developed and have great dangers They also have much of promise for the future, if we do not get involved in a suicidal nuclear war.

As scientists, it is very much our concern to understand the significance of recent events Russia was practically an underdeveloped country at the time of the Revolution forty years ago The launching of the "Sputnik" from this country became possible only because of the revolutionary progress of science and technology in Russia in the course of one single generation In Russia, as in all other industrialized countries of the world, scientific research and industrial production have been closely coupled; progress of one has been both cause and effect of an advance of the other. It is this integrated advance of science and industry which has made it possible for USSR to attain its present leading position in the whole world

Scientific research and economic development

In all industrialized countries we find a close association between the attention given to scientific education and research and the rate of increase of industrial production and, hence, of the improvement in the standard of living Consider the three nuclear Powers, UK, USA and USSR, and also two underdeveloped countries, China and India, which have the two biggest populations in the world and much natural resources Table 1 shows the population, production of steel, and output of energy in 1955 in these five countries. The equivalent total energy

Table 1: *Population and Production of Steel and Energy 1955*

country	population in million	electricity	steel (ingots)	coal	oil	energy (all forms) in terms of coal
		10^9 kwh		. million tons		
USA	165	629	106 2	448	336	1,364
USSR	200	170	45 3	276	71	442
UK	51	94	20·1	225	0 15	249
China	608	12 1	2 9	93	0 79	96
India	382	8 5	1·7	39	0 29	45

Sources: All the figures except population in China are taken from the *UN Statistical Year Book, 1956*: population, pp 21-36; steel, pp 261-262, coal, pp 138-140; oil, pp 143-144; electricity, pp 200-204 and energy (all forms), pp 308-310. The figure for oil in China relates to 1954 The Chinese population figure is taken from statistics prepared by the State Statistical Bureau of the People's Republic of China (in Chinese).

in terms of million tons of coal is given in col (7) which includes all forms of commercial energy but does not include fuel wood and dung In Table 2, col (3) gives the per capita national income at 1955 prices in the currency of the country concerned; col (4) the per capita production of steel in kilograms; and col (5) the total commercial energy in equivalent kilowatt hours Approximate data on expenditure on scientific research are given in cols (6), (7) and (8). The actual expenditure (expressed in rupees at official rates of exchange) is given in col (6), and is shown as a percentage of the national income in col (7) Finally, the expenditure on research per person is shown in col (8) More detailed information and comments are given in two Statistical Notes (1) and (2) at the end of the Address.

The estimates are admittedly approximate and there are well-known difficulties in international comparisons of income and expenditure Prices and the structure of prices vary widely from one country to another. Concepts and definitions used in different countries are often different. For example, the American figure for expenditure on research includes industries It is possible that research carried out in industrial concerns is not included in the Russian figure. Nevertheless some striking contrasts come out clearly in Table 2.

The three great powers have the highest per capita income, energy, steel and expenditure on research. China is way behind but has already outstripped India in all items, although only a few years ago China was less developed than India. Expenditure on research is Rs 65 crore in China compared to Rs 15 crore in India, or more than four times higher As a fraction of national income, China spends 0 4 per cent which is nearly three times higher than the Indian figure of 0 15 per cent The "per person" expenditure in China is Rs 1 1 per year which is again three times higher than the Indian expenditure of Rs 0 38 per year In 1943 Dr J C Ghosh in his Presidential Address to the National Institute had raised the slogan of "one per cent of the national income per year for scientific research " The three advanced countries are spending nearly twice as much at present; and China has

Table 2: *Economic Development and Expenditure on Research 1955*

country	estimates per person per year				approximate expenditure on research		
	national income		steel ingots	energy (all forms)	actual	p c of national income	per person
	unit	amount					
			kg	kwh	Rs crore	%	Rs
USA	$	2,000	644	13,753	2,550	1·8	154
USSR	roubles	5,000	226	3,367	2,200	1 8	110
UK	£	300	394	8 118	430	2 1	85
China	yuan	135	4 8	267	65	0 4	1 1
India	Rs.	250	4 5	200	15	0 15	0 38

Sources: Figures in col (3) are derived from the *Statistics of National Income and Expenditure, UN Statistical Paper, Series H*, No 10, for USA and UK; *Economic Bulletin of Europe*, May, 1957, for USSR; statistics prepared by the State Statistical Bureau of the People's Republic of China, for China; and *Estimates of National Income, 1948-49—1955-56*, Government of India, for India Figures in cols (4) & (5) are derived from Table 1. Figures in column (6) are collected from miscellaneous sources indicated in Statistical Note (2) at the end while figures in cols (7) & (8) are derived from the figures in col (6) and those in Table 1.

almost achieved half the target while, after 15 years, India has gone only one-sixth of the way.

Table 3 shows the available number and the out-turn of engineers and doctors in the five countries. Col (2) gives the population in million to serve as a basis for comparison; cols (3), (5), (7) and (9) give the years of reference Col (4) shows the estimated number of engineers available (in thousands), and col (6) the annual out-turn (in thousands). In the three advanced countries the out-turn figures refer to training at University level; in China and India the figures include both graduates and diploma-holders. Col (8) gives the available number of doctors (in thousands), and col (10) the annual out-turn (in thousands); the out-turn figures refer to graduates in all countries The corresponding numbers per million of the population are given in the lower half of the table.

The three advanced countries have much higher numbers of both "available" and "out-turn" of engineering and medical personnel. USSR has established a definite lead over both USA and UK, the actual number and proportionate out-turn of both engineers and doctors in USSR are more than double those of USA This indicates a striking superiority in technical man-power, the effect of which is bound to be felt in an increasing measure in future. Scientific and technical man-power requires a longer period of maturing than basic heavy industries. In this respect USSR now occupies, beyond dispute, the leading position in the world. It is reasonable to infer that this lead has some connexion with the launching of the "Sputnik".

China and India are much behind the more advanced countries. The available numbers of engineers and doctors are roughly of the same order in both China and India but China still has appreciably fewer than India on a population basis, namely, 132 engineers per million of the Chinese population against 188 engineers per million of the Indian population with 116 and 183 per million as the corresponding figures for doctors. It must be remembered that engineering and medical education of the modern type had started

Table 3: *Number and Annual out-turn of Engineers and Doctors*

country	1955 population (10^6)	engineers				doctors			
		total available		annual out-turn		total available		annual out-turn	
		year	number (000)	year	number (000)	year	number (000)	year	number (000)
USA	165	1950	518·8	1956	26·0	1955	218·1	1955	7·1
USSR	200	1956	721·0	1956	71·0	1955	299·0	1956	20·0
UK	51	1956	78·5	1954-5	2·8	1956	85·0	1952-3	1·9
China	608	1955	80·2	1955	18·8	1955	70·5	1955	6·8
India	382	1955	71·9	1955	7·0	1955-6	70·0	1954	3·1
		number of persons per million of population							
USA			3144		158·0		1322		42·5
USSR			3605		355·0		1495		100·0
UK			1539		55·0		1674		37·3
China			132		30·9		116		11·2
India			188		18·4		183		8·1

Sources: given in Statistical Note (3) at the end of the Address.

several decades earlier in India. China, however, has left India behind in the out-turn of both engineers and doctors. The number of engineers coming out every year is 30·9 per million in China or 60 per cent greater than the Indian out-turn of 18 4 per million in 1955. As regards doctors, the out-turn of China is 11 2 per million against 8 1 per million of India, or 40 per cent greater.

With the rapid expansion of scientific and technical man-power and of scientific research in USSR there has also been a rapid expansion in the industrial production of the country [1] The expansion of scientific and technical man-power and of scientific research, on one hand, and rapid increase of industrial production, on the other, are but two aspects of the same transformation. USSR and China (and India) have large natural resources which can be utilized for the benefit of the men who live in these countries Such utilization or exploitation of natural resources can be done only with the help of scientists, engineers, and technical personnel. It is clear that scientific research and availability of scientific and technical personnel are the important factors in the economic development and "power" of nations, however it may be measured It is also clear that India is lagging very much behind in these respects.

Economic and Social Conditions in India

Consumer Expenditure. The two great problems of India are poverty and unemployment which are but two aspects of economic stagnation and under-development. Since 1950 the National Sample Survey (NSS) has been collecting information on social and economic conditions in both rural and urban areas of India Some of this material has been given in the Statistical Appendix from which much interesting and significant information can be obtained I shall give a few selected examples

The following Table 4 gives in cols (1) to (4) information on the total consumer expenditure for the whole of India (rural and urban, excluding Jammu & Kashmir) during the period December 1955 to May 1956. Cols (1) and (3) give the percentage of the population, and cols (2) and (4) the limiting expenditure in rupees per person per 30 days

It will be seen from the first line that 5 per cent of the population or nearly 20 million spend less that Rs 3 2 per person per month; and from the second line that 10 per cent or more than 38 million people spend Rs 6 2 per head per month From the bottom line of col (2), we find that 50 per cent or *half of our countrymen, nearly 200 million in number, live on Rs 14 6 per month or less than half a rupee/day*[3] *per person* It would be also seen that even 90 per cent of the population spend less than Rs 35 8 per month or just over a rupee a day. That is, *only about 10 or 11 per cent of the population of India can spend more than one rupee a day.* This would give some idea of the poverty

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[1] Due to destruction of steel factories during the civil war, the production of steel had fallen to 200,000 tons in 1920 but rose to 18 3 million tons in 1940, dropped to 12 3 million tons in 1945 due to destruction during the war; and rose to 45 3 million tons in 1955 with a target of 68·3 million tons in 1960. Output of black coal (in million tons) increased from 99 4 in 1945 to 276 1 million tons in 1955 and has a target of about 415 million tons in 1960. The output of electricity in billion (thousand million) kilowatt hour rose from 43 3 in 1945 to 170·1 in 1955 with a target of 320 bkwh in 1960. The rate of increase in the USSR is far higher than that achieved in the USA, UK, or West Europe.

In China also the rate of development has been very rapid since the beginning of the First Five-Year Plan in 1953 Production of steel (in million tons) rose from 1 8 in 1953 to 5·2 in 1957 with a target of, possibly, 15 million tons in 1962. Production of coal (in million tons) increased from 67 in 1953 to 122 in 1957 and has a target of about 200 million tons in 1962. The output of electricity (in billion kilowatt hour) increased from 9 in 1953 to 19 in 1957 with a target of about 43 in 1962. (All figures have been taken from official Chinese sources).

[2] One rupee is about 21 US cents and 1 shilling 6 pence in British currency.

Table 4: *Distribution by size of (a) Consumer Expenditure· 1955-56 and (b) Land holdings* (1953-54) *all-India*

	by total consumer expenditure in rupees per person per 30 days[1]				by size of land-holdings in acres[2]			
	per cent of population	limit of expenditure in rupees	per cent of population	limit of expenditure in rupees	per cent of households	limit of size of land holdings	per cent of households	limit of size of land-holdings
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	upto	less than	upto	less than	upto	less than	upto	less than
1.	5 p.c.	Rs. 3 2	55 p c	Rs 15 7	5 p.c	0 2 acre	55 p c.	4·0 acre
2	10 ,,	,, 6 2	60 ,,	,, 16 9	10 ,,	0 5 ,,	60 ,,	4 7 ,,
3.	15 ,,	,, 8 4	65 ,,	,, 18 4	15 ,,	0 7 ,,	65 ,,	5 7 ,,
4	20 ,,	,, 9 8	70 ,,	,, 20 0	20 ,,	1 0 ,,	70 ,,	6 6 ,,
5	25 ,,	,, 10 4	75 ,,	,, 22 2	25 ,,	1 3 ,,	75 ,,	7 9 ,,
6.	30 ,,	,, 10 9	80 ,,	,, 24 9	30 ,,	1·7 ,,	80 ,,	9 7 ,,
7.	35 ,,	,, 11 6	85 ,,	,, 28 6	35 ,,	2 0 ,,	85 ,,	12 6 ,,
8.	40 ,,	,, 12 4	90 ,,	,, 35 8	40 ,,	2 4 ,,	90 ,,	16 2 ,,
9	45 ,,	,, 13 4	95 ,,	,, 44 2	45 ,,	2 8 ,,	95 ,,	26 0 ,,
10.	50 ,,	,, 14 6			50 ,,	3 3 ,,		

in which our countrymen have to live

Many other facts regarding conditions of living can be found from the Appendix Tables A 1.0, A 1.1, and A 1 2 The rich actually spend more on foodgrains but proportionally less in relation to their total expenditure as can be seen from Table A 1 1 However, both actual and proportional expenditures on sugar, milk and milk-products, and clothing are relatively much higher among the rich, showing that these are essentially luxury items. It is interesting to observe that medical care is apparently the greatest luxury, the poor can have very little of it, and medical expenses go up very steeply as the level of expenditure increases

Land owned by Households: Similar estimates are given in cols (5) to (8) of the same Table 4 in respect of the size of the holding of lands in acres owned by any assigned percentage of households who own 0·1 acre or more of land. (Households owning less than 0 1 acre were omitted to exclude landless labour and non-agricultural households). It is seen from this table that 20 per cent, or one-fifth of the households, have 1 acre or less; 50 per cent have less than 3 3 acre; 75 per cent have less than 7 9 acre,

Table 5: *Concentration curves of (a) consumer expenditure 1955-56 and (b) land owned by households 1953-54 all-India*

(a) persons or (b) households	consumer expenditure on all items by persons from		total land owned by households from	
	bottom (0)	top (100%)	bottom (0)	top (100%)
	cumulative percentages			
1 upto 5 p c	1 5	18 2	0 2	34 2
2 10 ,,	3 2	28 8	0 4	48 8
3 15 ,,	5 2	36 6	0 9	58 6
4 20 ,,	7 6	44 0	1 5	66 5
5 25 ,,	10 1	49 9	2·3	72 5
6 30 ,,	12 8	55 3	3 1	77 5
7 35 ,,	15 5	60·5	4 6	81 0
8 40 ,,	18 8	65 6	6 2	84 6
9 45 ,,	22·3	70·0	8·1	87·5
10 50 ,,	26·1	73 9	10 5	89 5

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[1] Based on National Sample Survey (NSS): 10th Round, December 1955—May 1956, All-India (rural and urban) excluding Jammu & Kashmir.

[2] Based on National Sample Survey (NSS): 8th Round, July 1954—March 1955, All-India rural area only.

and 90 per cent less than 16 2 acre. Most of the households in the rural area own very little land.

The disparity between the rich and the poor can be seen more clearly from Table 5 above. The percentage of the population or, alternatively, of households is shown in col (1). In each line, col (2) shows what percentage of total expenditure (of the whole population) is shared by the percentage of population from the *bottom* as given in col (1) of the same line; col (3) gives the share of the same percentage of persons but from the *top* Thus, the lower 5 per cent of the population of India share only 1 5 per cent of the total consumer expenditure, while the top 5 per cent of the population share 18 2 per cent of the total expenditure. We also find that while the lower 25 per cent of the population share 10 per cent of the total expenditure, the top 25 per cent share 50 per cent, and that the lower half has 26 per cent while the upper half of the population share 74 per cent of the total expenditure.

Similar estimates are given in cols (4) and (5) of Table 5 in respect of the proportion of land owned by different percentages of households. The bottom 5 per cent own very little land, only about 0 2 per cent or less, while the top 5 per cent own 34 per cent of all lands owned by households In the same way, it can be seen that the bottom 20 per cent have 1 5 per cent against 66 per cent of all lands owned by the top 20 per cent. The lower half of households have 10 per cent against 90 per cent owned by the upper half. Disparities are much higher at the top. For example, the top one per cent of households owns approximately 13 per cent of the total land; the top two per cent nearly 21 per cent; and the top five per cent of households own 30 per cent or almost one-third of all lands owned by households[1]. The concentration of land-holdings is clearly much greater than that of household expenditure.

Employment and Unemployment Some information on employment and unemployment is given in the Statistical Appendix, Tables A.3.1, A 3.2, and A 3.3 I should explain that there are great difficulties in adopting in India the concept of 'unemployment' used in the advanced countries of the world, where practically all gainfully employed persons receive wages and salaries or have earnings in money (except for time spent by members of a family on their own household work) It is, therefore, possible to specify in an objective manner whether a person is gainfully occupied or is out of work There are of course, technical difficulties of standardizing the definition of unemployment even in the advanced countries but these are not very serious In an underdeveloped country like India, on the other hand, there is inevitably a great deal of ambiguity in defining unemployment in an objective manner Much of the work in household enterprises, in both agriculture and cottage industries, is done by members of the household and is not paid for in money. Also, a large number of persons work on their own account, such as weavers, tailors, carpenters, smiths, barbers, small store-keepers, etc. These people may have enough work to keep them busy the whole day; or they may have to sit idle for a part or most of the time; or may have practically no work in hand, and yet they can never be called technically "unemployed" in accordance with the concept used in the more advanced countries. The above considerations must be kept in mind in interpreting the information given in the Statistical Appendix based on the National Sample Survey covering about 24,700 households in the 9th Round: May-August 1955, and covering about 17,600 households in the 5th and 6th Rounds, December 1952-August 1953. It must also be remembered that all estimates, being based on sample surveys, have margins of errors of sampling.

Subject to these warnings, we may say

broadly that about 160 million persons (or roughly 42 percent out of an estimated population of 382 million in 1955) were in the labour force, that is, were either engaged in work or were seeking work Among them, 2 2 million were "unemployed" in the technical sense of the advanced countries (Table A 3 1), which, however, has no clear meaning in India. In fact, only about 13 million persons, who work under Government and public authorities or in private organized large scale enterprises, have employment of the type usual in the advanced countries (Table A 3.2). The technical concept of "unemployment" can be strictly used only in the case of these 13 million persons (out of a total labour force of 160 million), but is not applicable to the remaining 147 million who work in household or small scale enterprises.

In an underdeveloped country it is, therefore, necessary to consider how many persons have to sit idle a part or most of the time for lack of work and other economic reasons. From the information collected by the NSS it would seem that nearly 20 million persons normally work one hour or less per day, 27 million work two hours or less per day, and nearly 45 million persons are engaged in gainful work for 4 hours a day or less [Table A 3 1, portion B.2]. In NSS, 5th and 6th Rounds: December 1952-March 1953, it was found that nearly 30 million persons have gainful work for less than 5 days in the month, 39 million less than 10 days, and 53 million less than 15 days in the month [Table A.3.1, portion B.3]. In another enquiry, NSS· 7th Round, October 1953-March 1954, it was found that about 45 million persons were working part-time. They were asked supplementary questions, and from the replies received it seems that among them about 10 million persons were not able to work full time partly on account of their own ill-health or on account of the illness of other members of the family; over 23 million (or about half) gave reasons of an economic nature such as lack of demand for their labour, lack of tools and raw materials, slack and off season, etc ; and 13 million gave other reasons. Finally, in NSS, 9th Round, in reply to a specific question, nearly 12 million persons stated that they were seeking additional work and would be available for 4 hours of work or more per day [Table A 3 1, portion B.1]

From the above account it would be seen that it is difficult to give a precise figure for unemployment or underemployment in India. The estimate would depend on which particular concept and definition is used to measure unemployment or underemployment However, it may, perhaps, be broadly stated that there can be scarcely any doubt that *10 or 12 million persons are either unemployed in the technical sense of the more advanced countries or are severely underemployed If consideration is extended to those who are sitting idle for more than half or two-thirds of their working time, the number would probably rise to 25 or 30 million persons*

Some more specific information is available regarding unemployment among the educated defined as matriculates and persons having higher qualifications It is estimated that their total number in 1955 was about 50 lakhs, out of which 4 7 lakhs (or 9 4 percent) were unemployed, most probably in the technical sense of the term as being out of a job or seeking a job as in the more advanced countries. It must be remembered in this connexion that in 1955 just over 4 lakhs of candidates passed the matriculation examination, and the number is rising from year to year. *There is already about* 10 *percent unemployed among the educated class. The proportion is likely to increase considerably in future which would have grave social and political implications.*

General and Professional Education: I shall now briefly consider the question of trained personnel. Some information regarding the number of persons passing the matriculation examination and acquiring other general or professional qualifications every year from 1950 to 1955 is given in Appendix Table A.3.4. Much interesting information can be obtained from this table I shall make only a few brief observations.

There has been fairly rapid all round progress in numbers. The number of matriculates increased roughly from 1 89 lakhs in 1950 to just over 4 lakhs in 1955 or has doubled in 5 years The rate of increase is about the same at other levels It is also seen that the number of candidates passing the intermediate examination is roughly 40 percent of the number who passed the matriculation examination two years earlier, the number taking the first degree is roughly 60 percent of the number who passed the intermediate examination two years earlier; and the number taking the master's degree is roughly one-fourth of the number who took the first degree, two years earlier These are approximate statistical proportions which would vary considerably from year to year but can give some idea of the structure of general education. As a very rough rule, out of 100 matriculates in any given year about 40 would pass the intermediate two years later; 24 would take the first degree after two more years, and 6 would take the master's degree two years later.

It is of interest to make some comparisons on the basis of the number of literates in India which was about 63 million in 1955. The number of matriculates was thus about 5,300 per million literates; and the number of first graduates about 900 per million literates in India. In contrast, the number of first graduates in UK is 450 per million literates or proportionately only half that of India.

One gets a general impression that the number of students in the university stage is increasing quite fast and is roughly doubling every five years. The rate of increase in the number of science students is, however, much smaller at all stages and the rate of increase of science students is also appreciably smaller than arts students at the intermediate and degree levels and is roughly the same at the stage of the master's degree. The position is thus not satisfactory from the point of view of scientific and technical man-power.

The fact that the "proportion of graduates to literates" in India seems to be roughly double that of the UK makes it possible that education at the university level in India is expanding in quantity at the cost of quality. This, I believe, is also the general impression among my scientific colleagues. It raises some serious questions It is true that when there is a large increase in the number of students, the average quality would usually decrease. It is doubtful, however, whether this has been the only reason We are aware that a very large number of natural and social scientists were appointed during World War II, and are still being appointed in Government posts at salaries much higher than those that can be offered by universities and scientific institutions In consequence there is a great shortage of competent and experienced teachers in the universities The expenditure on laboratories and scientific equipment has not kept pace with the expansion in the number of students and is extremely small in comparison with needs. The syllabus and courses of instruction are in many cases out of date All this requires to be changed.

Science Teaching: It is clear there cannot be any broad-based advance of science and scientific research in India without making university teaching more efficient and more oriented to present needs than at present. With this problem is linked the question of efficiency of science education in the top classes of secondary schools, to which I shall merely draw your attention but which I have no time to consider. It is necessary indeed to formulate a comprehensive scheme of science teaching, from the upper classes of secondary schools upto post-graduate teaching in the universities, and implement the same, in order to lay a sound foundation for science in India. The scientists have a very special responsibility in this matter. It is true, of course, that it would be necessary for Government to make important decisions of policy and to provide adequate funds But, on the technical side, improvements in science teaching and research can be brought about only through vigorous and untiring efforts of scientists themselves They have a triple task. They must take the initiative in formulating, at a concrete level and step by step, programme for the improvement of science teaching and research; and, secondly, persuade Government to take appropriate action in financial and policy matters. Thirdly, scientists should start doing whatever they can on their own; and then, as and to the extent Government support begins to be available, make the best use of such support for the promotion of science in India.

Scientific and Technical man-power

It is generally agreed that India would require a rapidly increasing number of scientists, engineers, and technologists in future. It is necessary therefore to attract a sufficient number of young men of ability to take up science as a career. The only way is to offer adequate economic and social incentives. Consider the position in the advanced countries of the world. USSR has established a definite lead over all other countries in scientific and technical personnel. Professors and research scientists, as a group, get the highest salary and have the highest status in USSR. The Academicians (members of the Academy of Sciences) have a life pension of 5,000 roubles (half of which would accrue to a surviving widow) in addition to the salary of the post It is being increasingly realized all over the world that it is this high social appreciation of scientists which is the real secret of the rapid advancement of science in USSR. In USA, UK and other countries of Europe, professors and scientists have a high social status but the position is not as satisfactory as in USSR, which has become a matter of serious concern to these countries.

The position of science professors and research scientists in India is most unsatisfactory compared to advanced countries. Scientists working in universities and in scientific institutions receive much less salary than scientists working under Government. Scientists in Government employment also are in an unsatisfactory position As a group (with a few exceptions) scientists receive less pay and have lower status than administrative officers. Also, scientists have very little say in the making of decisions in Government An urgent requirement for the advancement of science in India is to remove such disparities.

Scientific societies and planning

I should now like to draw attention to another problem which is likely to become increasingly serious in future In the Western countries scientific research and science teaching had developed at first in the universities, and later, in connexion with research in industry independently of Government control From the 17th century many scientific societies and institutions were established in the countries of the West for the promotion of science and scientific research. More recently Government began to sanction large grants for scientific research. In most countries the largest share of research funds now comes from Government. This has raised important questions of policy in regard to Government control over scientific research.

It is interesting to observe that in USSR an Academy of Sciences was established by the Communist Government at a very

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In USSR, China, and other socialized economics all expenses for research are provided by Government. In other countries also, scientific research is being increasingly financed by Government. Even in the USA, out of the total expenditure of $5·4 billion dollars (=Rs 2550 crore) in 1953, the share of Government was highest and 52 per cent. Industry came next with a contribution of 44 per cent. The share of universities was only 3 per cent and that of institutes only one per cent. Of the total expenditure, the biggest portion (72 per cent) was spent by industrial concerns, 18 per cent by Government agencies, and only 9 per cent by universities. It is interesting to note that of the money spent on research by industry, 60 per cent came from industry itself and 40 per cent from Government. (*Scientific American*, November 1957, pp 47).

early date as an autonomous institution independent of the executive control of Government. The Academy has been given great responsibilities and supplied with adequate funds for a wide range of functional activities in scientific research and the promotion of science. It maintains over one hundred scientific institutes spread over the country, and in 1957 had a total staff of 50,000, of whom 12,000 were professional scientists and 4,000 professors. The point to be emphasized is that in all advanced countries of the world, in the West as well as in USSR, there are well established scientific societies with a great tradition of scientific thinking and criticism which are outside Government and which can be relied upon to supply Government with independent advice in scientific matters.

It seems to me that there is need in India of functional scientific institutions which would be outside Government but which would take up, by agreement with Government, such scientific work or research or promotion of science or the coordination of scientific activities as can be done conveniently and efficiently by a non-official agency with the help of a whole-time staff of competent and high level scientists. Scientists engaged on such "decentralized" research or scientific activities, on a whole-time salary basis, would be independent of Government. In this way it would be possible to build up an organization or system of scientific thinking and criticisms which would be able to render great service to Government by offering unbiased and independent views in scientific matters. There is great need of such advice in connexion with planning and in the appraisal of the progress of plan projects.

To speak quite frankly, some of these ideas have come to mind, because I am not satisfied with the present activities of the National Institute of Sciences. I feel scientists must shoulder greater responsibilities in connexion with national planning. Coming together for occasional meetings is not enough. I should, therefore, like to see the National Institute of Science's undertake assignments related to planning for national development which would be done in a systematic and painstaking way by a whole-time or part-time paid staff. I have a feeling that it is only through work at a concrete level that we shall be able to develop seriousness of purpose and a sense of responsibility in scientific matters of importance for national development.

Strategy of Planning in India

The task of planning must be to improve continually the level of living, especially, of the 95 percent of the population who are poor, and to create enough new employments to get rid of the fear of unemployment It has been recognized for a long time that this can be done only through rapid industrial development As India has plenty of iron ore, coal, bauxite, etc., the key to industrialization lies in establishing the manufacture of heavy machinery, heavy electrical equipment (turbines, generators, switch and transmission gear), and machine tools. Once this is done, everything else can be gradually manufactured in India mostly out of domestic resources As more and more machinery becomes available, it would be possible to create more and more employment and continually to construct more machinery and expand the production of coal and electricity, steel and aluminium; fertilizers, cement and heavy chemicals, equipment for transport and communications; scientific instruments, etc.; and, in this way, produce more and more consumer goods and improve the level of living.

It has to be accepted, in principle, that until sufficient machinery and tools become available, it is essential to utilize idle hands for the production of cloth, household utensils and other consumer goods. This is for two reasons. Our greatest shortage is of machinery, while we have millions of unemployed persons sitting idle. Whatever machinery we can afford to import or manufacture within the country should be used to build up the basic industries which would produce more machinery, more steel, cement, fertilizers, electricity, etc. That is, we must not waste our meagre resources of foreign exchange to import non-essential consumer goods, or machinery for the manufacture of consumer goods which can be produced within the country by putting idle hands to work. Expansion of small scale and village industries would create employment all over the country, increase the supply of cloth and other consumer goods made by hand labour, and improve the level of living without hampering the expansion of basic industries.

A third point requires to be recognized. Agriculture and industry are closely interlocked in India. Industrial development is not possible without an increasing supply of cheap food and raw materials. On the other hand, in India, owing to scarcity of land, basic improvements in agriculture can be brought about only through the use of more fertilizers, more irrigation, and better methods of cultivation, all of which would have to depend on large scale industrial development. However, in the short run, a good deal can and must be achieved by intensive cultivation of land by hand and by improving conditions of living in rural areas through community projects, land reform, consolidation of holdings, village cooperatives, etc.

This brings us to the fourth point, namely, that planning in India must proceed at two different and clearly distinguishable levels or spheres One is concerned with questions of large scale industrial development which can be, and are, decided in every country by a small group of persons at the top. For example, the decision in 1949 to instal a million-ton steel plant, its reversal in 1950, and fresh decisions in 1953 and 1954 to expand steel production by 3 or 4 million tons were all taken by the Government of India without any consultations with the general public. It is proper for Government to make such decisions. It is also possible to implement the decisions without any difficulty as it would involve only a small number of persons. The position is entirely different in agriculture or in small scale and hand production which involve millions of households scattered over a very big country. Consider consolidation of holdings or village cooperatives. It is necessary, of course for Government to make policy decisions; but this by itself would not be sufficient because the implementation would depend on securing the willing cooperation or at least the concurrence of millions of persons in the villages. In the beginning, the organization of agriculture and small scale production, which may be called the "diffuse" sector, would be far more difficult than establishing large scale industries. The approach must be through institutional changes, spread of education, improvement of communication, etc., and, above everything else, by carrying conviction to the masses that Government is doing its best for national development. Success in establishing the basic industries would give Government increasing control over the national economy, and thus place Government in a strong position to make steady improvements in the diffuse sector and to secure the active support of the masses for national development.

Basic industries are thus of crucial importance in two different ways. Firstly, these alone can give us economic independence. Secondly, these alone can place Government in a position to make steady advance in the diffuse sector. The strategy of planning, therefore, requires the highest priority being given to the basic industries, namely, heavy machine building, heavy electrical equipment, machine tools, fertilizers, steel, cement, etc.

The Question of Foreign Exchange: It is true that, in the beginning, it is necessary for us to have both technical and financial help from outside India. Professor P M S Blackett, in his Presidential Address to the British Association for the Advancement of Science in September 1957 has pointed out the importance of outside help to an underdeveloped country in getting it off on its way to economic development. He has also given an inspiring lead by stressing the responsibility of the industrially advanced country in this matter from the world point of view. I fully appreciate the need of external aid.

I am also aware that grave difficulties have been created by the shortage of foreign exchange. A new approach was adopted in the Second Five Year Plan, and the size of the Second Plan was intentionally made much bigger than that of the First. It is not surprising that mistakes have been made at the stage of transition from a small to a much bigger scale of planned economy Techniques and tools of planning are not yet adequate and would have to be improved, and these questions are receiving the attention of Government and the Planning Commission. It would be appropriate, however, to examine the question of foreign exchange from the point of view of long-term planning.

I shall give a numerical example. Consider the question of foodgrains about which India is in a precarious position. From 1948 to 1953 we imported 19 3 million tons of cereals at a cost of about Rs 867 crore in 6 years, that is, at the average rate of about 3 2 million tons at a cost of Rs 145 crore per year [1] The average price paid was about Rs 450 per ton.

The population of India is growing at the rate of, possibly, 5 million persons per year.[2] It takes roughly one ton of cereals to feed 7 persons. At this rate, an additional supply of 700,000 tons of foodgrains *every year* would be required to keep pace with the growth of population. If we decide to purchase this quantity from abroad, we would require *every year* an additional Rs 30 crore of foreign exchange which would amount to Rs 150 crore in the course of one five-year plan (and this, also, only at the present rate of growth of population)

Consider the alternative method of using imported fertilizers to increase the production of cereals. One ton of ammonium sulphate, at a cost of about Rs 250 per ton, should normally give an additional yield of 2 or 2 2 tons of foodgrains. To give 700,000 tons more of foodgrains, the quantity of ammonium sulphate required would be 350,000 tons, of which the price would be Rs 8 75 crore or say Rs 9 crore. This would be the additional amount required *every year;* in the course of 5 years the total amount required would be Rs 135 crore.

A still better way would be to instal *every year* a new fertilizer factory to produce 350,000 tons of ammonium sulphate (roughly, like the factory at Sindri) The fixed investment would be about Rs 25 crore, of which the foreign exchange component would be only Rs 10 crore After the period of construction is over, each such factory would supply enough fertilizer to take care of the increase of population of one year The total expenditure in five years would be Rs 125 crore with, however, a total foreign exchange component of only Rs 50 crore.[3]

It is possible to go one step further, and establish immediately a heavy machine building factory in India, and, when this plant is constructed, to manufacture in India the machinery required, to set up a fertilizer factory. Of course, it is neither possible nor necessary to set up a machine building plant exclusively for the manufacture of big machinery for fertilizer factories, the work can be done in plants which would manufacture machinery for other industries as well. It is, however, possible to make rough calculations of cost, because in the case of heavy machine building plants the value of output is roughly equal to the value of the fixed investment. To produce machinery worth Rs 10 crore (the value of imports required to set up a Sindri-type plant) would thus call for an investment of about Rs 10 or, say, 15 crore with a foreign exchange component of possibly Rs 8 or 10 crore. This would be the (apportioned) cost in the first instance. The actual cost of setting up a fertilizer factory would be Rs 25 crore per year or Rs 125 crore in 5 years; but this would not involve any expenditure of foreign exchange.

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[1] Imports fell below one million ton in 1954 and 1955 but we have again started importing foodgrains heavily from 1956.

[2] There is some evidence to indicate that the rate of growth may be appreciably greater and as high as 6 or even 7 million per year. Although registration of births and deaths is known to be extremely defective, the fall in the recorded death-rate is probably real. Population estimates based on the National Sample Survey show high rates of growth in some of the rural areas.

Besides this, there will, of course, be current costs of intermediate products used up and wages paid.

[3] But when the intermediate products are available within the country and the output of wage goods industries is sufficient to meet the demand, such costs could be met entirely out of domestic resources. This would, no doubt, call for an expansion of the economy and would require organizational efforts; but similar and even greater organizational efforts would be needed to produce the goods to be exported to meet the larger requirements of foreign exchange in the other cases.

To sum up, in order to feed the fresh additions to the population at the rate of 5 million persons per year, it would be necessary to provide an additional quantity of 700,000 tons of foodgrains *every year* which would require Rs 450 crore of foreign exchange over a period of five years. The cost can be reduced to Rs 135 crore of foreign exchange in a 5-year period, if an additional quantity of 350,000 tons of ammonium sulphate is ordered from abroad *every year*, at least two years in advance of the crop season. The cost can be further reduced to Rs 125 crore (out of which the foreign exchange component would be Rs 50 crore) over a five-year period, if a new fertilizer factory of 350,000 ton capacity is started *every year;* this would call for decision 4 or 5 years ahead of the crop season concerned. The apportioned cost of a heavy machine building factory which would manufacture machinery in India to instal *every year* a new fertilizer factory of 350,000 ton capacity[1] would be, however, so small as Rs 12 or 15 crore with a foreign exchange component of perhaps Rs 8 or 10 crore. Such a decision would have to be made only once but 8 or 10 years in advance of the season in which the fertilizer would be used.

The above account is, no doubt, oversimplified; but it brings out clearly one important point. In India it is of the greatest importance to take a long view of planning. Additional requirements of foodgrains to cope with the growth of population can be met with an (apportioned) investment of only Rs 15 or 20 crore and of foreign exchange of Rs 8 or 10 crore, provided a decision can be made 8 or 10 years in advance of the year in which the food would be consumed. If the decision is made 4 or 5 years in advance, the cost would increase to Rs 125 crore with a foreign exchange component of Rs 50 crore If the decision is made a couple of years ahead, the cost would increase to Rs 135 crore in foreign exchange to import fertilizers; and if the decision to import foodgrains is made only from year to year the cost would go upto Rs 450 crore in foreign exchange. *Wise utilization of Rs 10 crore of foreign exchange once for all can lead, in time, to a saving of Rs 450 crore of foreign exchange in imports of foodgrains over a period of 5 years.*

Similar considerations hold good in other crucial sectors. An investment of Rs 150 crore, including Rs 80 crore of imported machinery, would be required to instal a million-ton steel plant with a product value of Rs 40 or 45 crore. A heavy machine building factory with an investment of

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[1] To give one example, it is worth mentioning that machine tools formed roughly 3 per cent of industrial equipment (in value) over a long period in the USA On this basis Rs 20 crore worth of machine tools would suffice for the manufacture in India of about Rs 600 crore worth of industrial equipment which, in its turn, would enable industrial investments being made to the extent of *at least* Rs 1000 crore per year basically out of our own resources. (*The Machine Tool Industry*, New York, Clark, Dodge & Co, May 1948).

[2] *Science and Culture*, October and November, 1957.

There is great scope for the use of fertilizers in India; some relevant information is given in Statistical Notes on the Use of Fertilizers.

Rs 80 crore, with foreign imports worth about Rs 50 crore, would produce every year machinery worth roughly Rs 80 crore or the equivalent of imported machinery needed to set up a million-ton steel plant. Once such a heavy machinery factory gets into production, it would be possible to start a new million-ton steel plant *every year* out of our own resources. An investment of Rs 30 crore in a plant to manufacture mining machinery would produce goods worth about Rs 30 crore per year. An investment of Rs 100 crore in heavy electrical equipment (generators, switchgear, heavy motors, rectifiers, transformers, etc) would give products of the value of about Rs 70 crore per year; and so on.

Need of Long-term Planning. From the point of view of industrial development over a period of 15 or 20 years there cannot be any doubt that the correct policy would be to establish the heavy machinery industries. Consider, purely for purposes of illustration, the following programme of investments with a rough value of the product given within brackets in each case.—heavy machinery Rs 150 crore (150 crore), heavy electrical equipment Rs 100 crore (70 crore), turbines Rs 20 crore (12 crore), mining machinery and drilling equipment Rs 30 crore (30 crore), machinery for chemical engineering Rs 25 crore (25 crore), machine tools[1] Rs 30 crore (20 crore), aluminium Rs 25 crore (5 crore), and, say, another Rs 70 crore for other basic industries giving a total investment of about Rs 450 crore with foreign exchange requirements of the order of Rs 300 crore over a period of five years. I am aware that foreign exchange would also be needed to expand transport and other facilities but provision has been already made for this and for steel and other investments in the Second Plan.

The point I am emphasizing is that Rs 300 crore of foreign exchange invested in suitable basic industries over a period of 5 years would establish a sound foundation for future industrial development and would enable us to manufacture essential capital goods within the country. (I am not suggesting that we should reduce our imports. On the contrary, we should try continually to expand our foreign trade. But we must attain as soon as possible a position in which, if necessary, we shall be able to manage on our own in an emergency.) We have made some real advance during the First Five Year Plan. It has been a very wise and farsighted decision to develop atomic energy, for which we have much natural resources. Dr H Bhabha has shown in a recent article[2] how great would be the benefit of atomic power electricity to Indian economy. Good progress is being made with steel. It is now necessary to make similar farsighted decisions to establish the basic heavy industries.

I should like to refer in this connexion to some recent trade statistics Indian exports amounted to Rs 597 crore in 1954-55; Rs 641 crore in 1955-56; and Rs 637 crore in 1956-57. Imports in these three years were respectively Rs 684 crore, Rs 757 crore, and Rs 1,077 crore. It would be noticed that the increase in imports in 1956-57 over 1955-56, that is, in one year was Rs 326 crore; and in 1956-57 over 1955-56, that is, in two years was Rs 393 crore, out of which the increase on private account was Rs 272 crore. I may also mention that the Government outlay on the First Five Year Plan was nearly Rs 2,400 crore, and the outlay on the Second FYP is expected to be roughly double. It is in the context of the above figures that one must view the proposal to invest Rs 450 crore and utilize Rs 300 crore foreign exchange to build up the basic industries. After the factories come into operation, there would be a saving of Rs 300 or Rs 350 crore of foreign exchange in the import of capital goods. This is the crucial issue of planning in India.

Finance and balance of payments are important aspects of planning; and there is no conflict between financial planning and physical planning. But it must be kept in mind that, in an underdeveloped country, the physical view is of basic importance. In one single year, 1956-57, our imports suddenly exceeded exports by

Rs 440 crore. If by some happy chance, Rs 300 crore out of this amount had been utilized to purchase capital goods required to establish the basic industries, then in five years' time we would have won our economic independence and would have overcome difficulties of foreign exchange permanently. Although the accounting position would have been the same, the real position would have been entirely different and ever so much better.

Planning in China: It is instructive to consider what happened in China. Mr. Li Hsien-nien, Vice-Premier and Minister of Finance of China, in his speech to the First National People's Congress in Peking on 29 June 1957 (supplement to *Hsinhua News Agency Release, Peking*) stated that China has received foreign loans amounting to 2,174 million yuan (=Rs. 435 crore) before 1953, and 3,120 yuan (=Rs 624 crore) for China's First Five Year Plan from 1953 to 1957. The total amount of the loan was thus Rs. 1,059 crore. A good part of this was used for rehabilitation after the present Government came into power (as stated by the Finance Minister); and a part, no doubt, was used for military expenses during the war in Korea. However, with the whole of the second loan of Rs 624 crore and a part of the first loan China rapidly developed the basic industries (heavy machinery, heavy electricals, machine tools, steel, fertilizers, trucks, etc.). The Finance Minister of China appreciated the help received from USSR, but stated "*we may say that we are now in a better position to rely on our own accumulation* [i.e., investment] *to carry on national construction.*"

It is important to note that foreign credit had tapered off rapidly. In the same speech the Finance Minister stated that foreign loans constituted 117 million yuan or Rs 23·4 crore in 1956, and 23·3 million yuan or only Rs 4 7 crore in 1957. China has a foreign trade which is roughly of the same size as India on a per capita basis. Although foreign loans would be of help and would make the task lighter, it seems that China will not have to worry about foreign exchange for essential requirements in future, and would be able to manage, if necessary, on the trading surplus. It may be mentioned that India received about Rs 200 crore of foreign assistance, roughly half in grants and half in loans, during the First Five Year Plan; and has fairly firm authorization of receiving at least Rs 600 crore of foreign assistance during the Second Five Year Plan. India also had foreign assets (held by the Reserve Bank) to the extent of Rs 723 crore in 1951-52 and Rs 746 crore in 1955-56 at the end of the First Five Year Plan which China had lacked. The foreign exchange position in India was thus much more favourable.

In Chinese planning the highest priority was given to develop those basic industries which would enable China to manufacture, within the country, essential capital goods required for rapid industrial development in future. Remembering that the Chinese economy is bigger than ours, it is of interest to note that China has "got off" on the way to industrialization out of its own resources with comparatively less foreign exchange than India. In contrast, India may continue to have foreign exchange difficulties for some considerable time to come in the absence of wise planning.[1]

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[1] The Indian Industrial Delegation which visited USA, Canada, UK, West Germany and other countries in Europe in September-November 1957, referring to foreign investments in Canada in its Report to the Federation of Indian Chambers of Commerce and Industry, stated:

> "Eight hundred dollars per capita foreign investment means nearly Rs 4,000 in Indian currency and at that rate and for such high development India should require Rs 1,60,000 crore (Rupees one lakh sixty thousand crore) of investment in India, of which at least one-third, viz., nearly Rs 50,000 crore would have to be in foreign currency! This can only be a dream. The conclusion to draw is that India cannot be developed without foreign capital which we shall continue to need for at least the next 25 years and in substantially large amounts" (p 27).

This attitude of mind is in sharp contrast to the outlook in China where, with a fifty per cent bigger population than Indian, the national economy got off on the way to rapid economic development with the help of foreign loans of only Rs 1,059 crore spread over 7 or 8 years.

The Chinese example merely corroborates what an objective scientific analysis had brought out, namely, that India could have built up, and can still build up, with the help of only a few hundred crores of foreign exchange those basic industries which would give her economic independence

Self confidence and Economic Independence: It is our responsibility, as scientists, to work out the logic and techniques of planning suited to India It is our responsibility, as scientists, to educate and convince our countrymen that India is a great country with vast resources, natural and human. We have the responsibility to use these resources to improve the level of living of our countrymen and to promote science and culture. We should welcome foreign help and cooperation, especially, in science and technology and in cultural matters Also, we must realize that it is not necessary continually to depend upon help from abroad. We must overcome the defeatist attitude which would make us continually ask for foreign loans. We must realize that political independence is not enough; we must win economic independence. We have the ability and the responsibility to make rapid economic advance with our own resources, and with hard labour, scientific thinking, wise decisions, and seriousness of purpose We must have faith in ourselves.

Statistical Notes

Notes on Table 1: In Table 1 figures have been given in metric tons. The Chinese official estimate of population in 1955 has been given instead of the UN estimate Electricity production in China and India excludes generation in enterprises for their own use Figures of energy (all forms) presented in col (7) refer to the gross inland consumption of commercial fuels and water power, expressed in terms of coal equivalent. Production data include chiefly coal and lignite, gasoline, kerosene and fuel oils, natural gas, and hydro-electric power; electricity produced by using the above fuels has been excluded. No account has been taken of fuel wood and other vegetable fuels and peat for want of adequate data. These possibly provide a major share of the energy supply in all but a few countries. In India, for example, a United Nations source (*World Energy Supplies in Selected years, 1929-50*) gives a figure for 1949 of about 84 million tons in coal equivalent of energy from such sources (mostly dung and fuel wood) compared to a figure of 35 million tons in coal equivalent for all commercial sources of energy quoted in Table 1 Thus we get a ratio between 2 and 3 to 1 between non-commercial and commercial sources in India The corresponding figure for USA is only 1 is to 20 For India, the percentage distribution of all energy may be given as: commercial energy (19%); non-commercial sources such as fuel wood, dung, etc (44%), animal effort (33%); and human effort (4%) with total (=100%) The UN publication used above did not include the last two sources.

Notes on Table 2: In Table 2 the national income figure for USSR is calculated from an estimate given in the *Economic Bulletin for Europe*, May, 1957 on the assumption that one-third of the gross savings comprise depreciation Other figures have been taken from sources referred to in the footnote to the table and have been rounded off Also, all the figures have been expressed in national currencies. The conversion factors between the various currencies used are 1 \$=4·75 Rs, 1 £=13·3 Rs, 1 rouble=1·2 Rs and 1 yuan=2 Rs, at current official exchange rates The exchange rates and the figures in col (3) would give some indication of the wide difference in the level of living between advanced and underdeveloped countries, any finer comparison between per capita incomes is fraught with grave dangers of error because of structural dissimilarities in prices

The per capita figures in Table 2, col (4) are obtained by using the output and population data in Table 1, and figures in col (5) are directly derived from *UN Statistical Year Book* 1956 in terms of coal equivalents (p 308 -10), the conversion factor used being 1 ton of coal = 1667 kwh of energy

Greater difficulties are associated with the derivation of the expenditure on research given in col (6) because of inadequacy of information The figure of \$ 5·4 billion dollars used for USA relates to 1953 and is on the basis of a report on *Funds for Basic Research in the United States* 1953 published by the National Science Foundation, USA; and also briefly reported in the *Business Week*, 23 November 1957. It was noted that only about 8 per cent of the amount is devoted to fundamental research. The percentage for USA given in col (7) is computed on the basis of national income for 1953.

The expenditure on scientific research in USSR is taken as 18·2 billion roubles on the basis of a report in the *Times of India* of a message dated Moscow, 20 December 1957, which was later confirmed in other communications.

The expenditure on scientific research in the UK is taken to be £325 million on the basis of an article, "Highly trained technical man-power in Western Europe," *Economic Bulletin for Europe*, May 1957.

The figure used for scientific research in China is 327 million yuan (=Rs 65·4 crore approximately) on the basis of the Finance Minister's speech on the budget for 1957 (July 1957). It should be noted that this expenditure is on scientific research proper and excludes a considerably larger figure (637 million yuan=Rs 127 4 crore) for higher education. However, we have to take cognizance of the fact that in China and USSR the definition of 'science' is wider and includes some of the social sciences (economics, linguistics, history, etc., which are not reckoned as science in Western countries) but excludes art, literature, etc. This would give a higher total figure for research in socialist countries. On the other hand, much of developmental research in engineering and technology is probably included under industries in socialist countries.

The figure for expenditure on scientific research in India has been arrived at on the basis of Government budget accounts and financial statements. Attempts have been made to exclude expenditure on higher education and certain promotional outlays; but expenditure on research in social sciences, such as economics and statistics has been include. No account, however, has been taken of research met exclusively by bodies other than Government; but its magnitude is small in India. The figure of Rs. 15 crore used is, at best, a dimensional estimate.

Exact comparisons are not possible because the definition of "scientific research" for budget and accounting purposes varies from one country to another. It is, in any case, difficult to demarcate research in applied science, in a precise and comparable way, from developmental work in engineering and technology The figures given, however, give a broad idea of the position in the different countries.

Notes on Table 3. *USA*· Data on available number of engineers and doctors as well as the figure of annual out-turn of doctors are taken from the *Statistical Abstract of USA*, 1957. The figure for annual out-turn of engineers is quoted from "Trained Man-power, USA *vs* USSR," *Monthly Review*, New York, April 1957.

USSR: Regarding engineers. both the figures are based on Soviet official statistics (in Russian). The figure of number of doctors available is taken from the English language publication, *National Economy of USSR: Statistical Returns*, while the out-turn figure is from the *USSR Reference Book*, November 1957.

UK: Both the figures for engineers are taken from "Highly trained technical man-power in Western Europe," *Economic Bulletin for Europe*, May 1957. The Annual Report of the British Medical Association, 1955-56 (Supplement to the *British Medical Journal*, April 7, 1956) gives the total membership of the Association as 68,306 in March 1956 and states that this number represents 80% of the total number in the profession; the available number of doctors is estimated on this basis The figure of annual output is obtained from G D H. Cole: *Post-War Condition in Britain*, 1956.

China· All the figures are based on the statistical returns for the People's Republic of China prepared by the State Statistical Bureau (in Chinese) However, a base figure of the available number of engineers in 1952 has been taken from Solomon Adler: *Chinese Economy*.

India: The out-turn figures are based on the *Educational Statistics of India*. The available number of engineers is taken from *Man-power Studies No. 5 Engineers in India· Number and Distribution* 1955, (Planning Commission, October 1957) The number of doctors is based on information available in the Planning Commission.

Notes on the Use of Fertilizers: In a review by the Indian Council of Agricultural Research on "The Use of Fertilizers on Foodgrains"[1] the response, standardized to 20 lbs. N (=100 lbs of sulphate of ammonia) per acre, was given as 3 4 maunds (or 274 lbs) of rice per acre, 2·8 maunds (or 230 lbs.) of wheat per acre, and between 1·7 and 3·1 maunds (140 lbs. and 255 lbs) of other cereals per acre For paddy the water supply was presumably adequate Experiments were reported for wheat from both irrigated and unirrigated crops; the response on unirrigated land was 1·7 maunds (140 lbs.) per acre compared to 2 8 maunds (230 lbs) per acre on irrigated land The authors pointed out that—

> "when the total supply of fertilizer is severely limited, the greatest natural benefit will accrue if small dressings are used on a large area of crop rather than heavy dressings on a small part of the area. . The first step is to ensure that available supplies are distributed over a large area of potentially responsive land; the second step is to increase supplies so that all areas likely to benefit considerably can have a small dressing; only thirdly does the increase of dressings to optimal levels become a desirable national policy" (p. 14).

The authors concluded that nitrogen response of 2·5 maunds (=206 lbs) of grains per acre from 20 lbs N per acre (=100 lbs. sulphate of ammonia) was "a reasonably representative figure for all cereals" (p. 15).

From information supplied by ICAR for a later

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[1] By F Yates, D Finney and V G Panse: ICAR Research Series No 1, 1953.

(TCM) series of field trials on rice and irrigated wheat conducted during the three years 1953-54 to 1955-56 at community project centres distributed over the whole country, it appears that the nitrogen response for a first dose of 20 lbs. of nitrogen per acre was about 3 maunds (247 lbs) of both rice and wheat per acre; and for a dose of 40 lbs of nitrogen per acre the response was 4·5 maunds (370 lbs) of rice per acre and 4·7 maunds (380 lbs) of wheat per acre.

There is a gradual falling off in the response with higher doses of nitrogen; but from the results given above it is clear that upto about 20 lbs of nitrogen (100 lbs of sulphate of ammonia) a response of 200 lbs or twice by weight of foodgrains can be expected on an average with confidence.

The net area sown in India was 313 million acres and the gross area sown including double cropped land was over 351 million acres in 1953-54 The gross area irrigated was about 60 million acres The total area under rice is about 78 million acres, out of which about 26 million acres are irrigated leaving a balance of about 52 million acres of unirrigated rice land, much of which would normally have adequate rainfall We thus have about 34 million acres of irrigated land under crops other than rice, 26 million acres of irrigated rice land, and 52 million acres of unirrigated land under rice giving a total of 112 million acres of land, for which the water supply is likely to be fairly adequate for the use of fertilizers At a rate of application of 20 lbs of nitrogen per acre there should not be any difficulty in using upto one million tons of nitrogen or 5 million tons of sulphate of ammonia for this type of land alone This is a safe estimate of minimum requirements. For the remaining 200 million acres of land if we accept a comparatively small dose of 10 lbs of nitrogen per acre on an average, we could use nearly the same quantity again at the second stage This would raise the requirement to about 10 million tons of sulphate of ammonia per year. For 112 million acres of land with good supply of water it would be possible to increase the dose upto 40 lbs of nitrogen per acre which would require nearly another 5 million tons of sulphate of ammonia. These very rough calculations indicate that India may be able to use without any difficulty upto 15 or 16 million tons of sulphate of ammonia per year, that is, can afford to instal 40 or 45 factories of the Sindri capacity of about 350,000 tons per year.

We may also consider the question from the point of view of rainfall. There are about 50 million acres of land under cultivation which get more than 50 inches of rainfall per year, and about 87 million acre under cultivation with an annual rainfall of roughly between 40 and 50 inches. Out of these 137 million acres about 36 million acres are irrigated leaving a balance of about 100 million acres of unirrigated land with annual rainfall of about 40 inches or more The balance of irrigated land is about another 30 million acres giving a total of about 130 million of acres under cultivation which is likely to have enough water for the profitable use of good doses of fertilizers On the other hand only about 50 million acres of land under cultivation in India receive less than 30 inches of rainfall per year; and of this about 12 million acres are irrigated This would leave something like 38 million acres of land which may be really unsuitable for the use of fertilizers.

I may further mention that the rate of application of nitrogen in many countries is very high[2] For example, the natural average dose of nitrogen in lbs per acre over all cultivated area in 1955-56 was as follows· Belgium 73, East Germany 42, West Germany 48, Netherlands 156, Norway 38, UK 37, Japan 98 and Egypt 38 compared to 0 86 lbs per acre with a total consumption of 145 000 tons of nitrogen or 725,000 tons of sulphate of ammonia in India These figures also indicate that there is great scope for the use of fertilizers in India The proposal made in my Address of installing only one fertilizer factory of the same capacity as Sindri per year is thus quite modest It is worth mentioning in the present connexion that there is some evidence to suggest that the actual rate of growth of population may be appreciably greater than 5 million per year and may be 6 or 7 or even more per year It would be wise to instal two such factories per year and this can be done without any fear of the saturation limit of utilization being reached in 15 or 20 years.

Household Consumer Expenditure

1 Since 1950 the National Sample Survey (NSS) has been collecting a wide variety of social and economic statistics from all over the country A great deal of information has thus become available on household expenditure on items of consumer goods such as foodgrains, sugar, milk and milk-products, or all food items taken together, clothing, medical expenses, etc , as well as the total expenditure on all items for a period of 30 days Data collected in the NSS: 10th Round (December 1955—May 1956) for 2754 sample households have been used to show some interesting facts in Tables A 1 0, A.1 1, A1 2 and A 1 3 For each household it is possible to calculate the "expenditure per person" by dividing the total expenditure on all consumer goods by the number of persons in the household In this way each person in the sample would be labelled by the "expenditure per person" of the household to which he belongs. It is then possible to classify all the individuals included in the sample into a number of groups or classes of expenditure level.

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[1] *Agricultural Statistics of Reorganised States*, Government of India, 1956-57.

[2] Year Book of Food & Agricultural Statistics: Production, Vol 10, Part I (FAO), 1956.

For example, in Table A.1 0, the individual persons were classified into groups having 'expenditure per person up to Rs. 8', 'between Rs 8 and Rs 11,' 'between Rs. 11 and Rs 15,' etc, and finally 'Rs 55 and above.' These class-ranges are shown in the top line of Table A.1.0 at the heads of cols (1) to (13). Information on different items is given in different lines separately for each class-range in the corresponding cols (1) to (13).

2. In the first portion of the table the average expenditure per person in rupees per 30 days is shown for 4 'food' items in lines 1 to 4, the total expenditure on food items in line 5, on clothing medical expenses and 'others' in lines 6-8; non-food total in line 9; and finally the expenditure on all items of consumption in line 10.

3. The expenditure on each item can be expressed as a percentage of the total expenditure given in line 20. These percentages are shown in lines 11 to 20 and show many interesting features The percentage expenditure on foodgrains (line 11) is over 55 per cent in the poorest group in col (1) and decreases to about 17 per cent in the highest group in col (12) The total expenditure on food (line 15) falls from 79 per cent at the bottom in col (11) to 44 8 per cent at the top in col (12) with an overall average of 65 4 per cent for all families. This shows that for India as a whole, food items make up about two-thirds of the household expenditure; in the poorest section it can be as high as four-fifths. Many other comparisons can be made on the basis of the results given in this table.

4. The average size of households, that is, the number of persons in the household is given in line 23; the estimated number of households (in million) in line 24; the estimated number of persons (in million) in line 25. It appears that, according to the NSS. there were nearly 80 million households and 385 million persons in India at the time of the survey. The expenditure in Rs crore per 30 days is also given in lines 26 to 28 The household budget of India came to about Rs 722 crore per 30 days, out of which about Rs 472 crore were spent on food and Rs 250 crores on non-food items.

5. Line 21 gives the percentage of persons in each expenditure class. From this line it can be seen that 14·01 percent of the population spend less than Rs 8 per person in 30 days. The next line 22 gives the accumulated percentages which is obtained by adding the figures in successive columns This is very convenient, because it makes it possible to see directly the percentage of the population spending less than a specified amount. For example, from col (2) it would be seen that 31·32 percent or almost a third of the population spend less than Rs 11 per person per 30 days; from col (4), that 52·2 percent or more than half the population spend less than Rs 15[1], from col (9), that nearly 90 percent of the population spend less than Rs 34[2]. This brings out the actual level of living of 90 percent of our countrymen.

6 The above information has been shown in a graphical form given in the chart in "Curve A on p 76 · Expenditure on all items in rupees" (per person per 30 days) in a solid line in the upper left hand corner of the chart The vertical scale on the left gives the cumulative percentage of the population and the horizontal scale at the top (in solid line) gives the scale of expenditure in rupees per person per 30 days. It is easy to read off from this graph the percentage of persons having an expenditure below any assigned value From this it is also possible to obtain (by subtraction from 100) the percentage of persons having an expenditure greater than any assigned value It is, of course, also possible to obtain for any assigned percentage the limiting value of the expenditure These values are given in Table 3 in the main text

Percentage expenditure on consumption

7 The information given in Table A 1 0 is shown in a different form in Table A 1.1. In each line the average expenditure for all classes, given in col (13) of Table A 1.0, is adopted as the basis for comparison and is put=100 Each figure in the same line is then expressed in the form of a percentage of the figure in col (13) These are given in the form of index-number in Table A 1 1 and show how the expenditure on each item and the value of other quantities increase with an increase in the level of expenditure

8. For example, in line 1 for foodgrains, it is seen that in col (1) the expenditure on food is 53 percent of the average expenditure for all classes taken together. In contrast, in col (12), the highest group, the index-number is 211 showing that the relative expenditure on foodgrains is double that of the general average. Also, comparing the index number 211 with the index-number 53, it is seen that the expenditure is four times greater in the top group compared to the bottom group For sugar (line 2), the bottom and top index numbers are 18 and 473 respectively showing an increase of 26 times Similar comparisons can be made for other items; but, because of errors of sampling, the comparisons should not become too refined A glance at col. (12) would also show that expenditure in the top group is relatively much greater on non-food items (710) compared to food items (394) and very high (907) in the case of medical expenses. In fact, medical care would seem to be the highest luxury in India which only the richer people can afford.

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[1] Approximately $3 (three US dollars) and British 22s 6d or US 10 cents and 9 pence per head per day

[2] Approximately $7 (seven US dollars) and British 51 shillings or less than US 25 cents and British 1s. 6d. per head per day.

Table A 1.0: *Consumer expenditure in rupees per person for a period of 30 days with percentage of total expenditure. all-India (Rural and Urban) 1955-56*

items	expenditure classes in rupees per person per month												
	Rs. 0-8	8-11	11-13	13-15	15-18	18-21	21-24	24-28	28-34	34-43	43-55	55 & above	all classes
(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	average expenditure in rupees per month												
1. foodgrains	3 49	4 69	5 89	6 35	6 93	7 58	8 26	8 52	8 71	9 33	10 08	13 98	6 61
2. sugar	0 09	0 20	0 25	0 36	0 42	0 52	0 65	0 77	1 05	1 13	1 46	2 41	0 51
3. milk & products	0·15	0 43	0 66	0 92	1 11	1 78	2 15	2 69	3 69	4 71	9 98	8 56	1 75
4. other food	1 22	1 85	2 34	2 73	3 28	3 54	4 31	4 81	5 67	6 01	7 43	12 34	3 39
5. food total	4 95	7 17	9 14	10 36	11 74	13 42	15 37	16 79	19 12	21 18	28 95	37 29	12 26
6. clothing	0 21	0 53	0 79	1 03	1 43	1 92	2 19	2 60	3 86	4 93	4 33	10 24	1 77
7. medical	0 01	0 09	0 11	0 19	0 27	0 37	0 46	0 51	0 84	1·21	1 73	3 90	0 43
8. others	1 09	1 62	1 94	2 38	3 05	3 83	4 49	5 89	6 86	10 40	12 23	31 86	4 28
9. non-food total	1 31	2 24	2 84	3 60	4 75	6 12	7 14	9 00	11 56	16 54	18 29	46 00	6 48
10. total (all items)	6 26	9 41	11 98	13 96	16 49	19 54	22 51	25 79	30 68	37 72	47 24	83 29	18 74
	percentage of total expenditure												
11. foodgrains	55 75	49 84	49 17	45 49	42 30	38 79	36 69	33 04	28 39	24 73	21 34	16 78	35 27
12. sugar	1 44	2 13	2 09	2 58	2 55	2 66	2 89	2 99	3 42	3 00	3 09	2 89	2 72
13. milk & products	2 40	4 57	5 51	6 59	6 73	9 11	9 55	10 43	12 03	12 49	21 13	10 28	9 34
14. other food	19 48	19 66	19 52	19 55	19 88	18 12	19 15	18 64	18 48	15 93	15 72	14 82	18 09
15. food total	*79 07*	*76 20*	*76 29*	*74 21*	*71 19*	*68 68*	*68 28*	*65 10*	*62 32*	*56 15*	*61 28*	*44 77*	*65 42*
16. clothing	3 35	5 63	6 59	7 38	8 67	9 83	9 73	10 08	12 58	13 07	9 17	12 29	9 45
17. medical	0 16	0 96	0 92	1 36	1 64	1 89	2 04	1 98	2 74	3 21	3 66	4 68	2 29
18. others	17 42	17 21	16 20	17 05	18 50	19 60	19 95	22 84	22 36	27 57	25 89	38 26	22 84
19. non-food total	*20 93*	*23 80*	*23 71*	*25 79*	*28 81*	*31 32*	*31 72*	*34 90*	*37 68*	*43 85*	*38 72*	*55 23*	*34 58*
20. total	100 00	100 00	100 00	100 00	100 00	100 00	100 00	100 00	100 00	100 00	100 00	100 00	100 00
21. percentage of persons	14 01	17 31	11 74	9 14	11 55	8 21	7 04	5 53	5 17	4 85	2 59	2 86	100 00
22. cumulative percentage	14 01	31 32	43 06	52 20	63 75	71 96	79 00	84 53	89 70	94 55	97 14	100 00	—
23. size of households (persons)	5 40	5 36	5 72	5 00	4 85	4 57	4 48	4 39	4 05	4 49	3 30	3 38	4 83
24. no. of households (million)	9 99	12 44	7 91	7 04	9 18	6 92	6 05	4 85	4 91	4 16	3 02	3 27	79 74
25. no. of persons (million)	53 96	66 67	45 21	35 21	44 50	31 62	27 12	21 32	19 91	18 68	9 99	11 03	385 22
	total expenditure in Rs crores per 30 days												
26. on 'food' items	26 69	47 83	41 33	36 48	52 23	42 43	41 68	35 79	38 08	39 58	28 92	41 14	472 18
27. on 'non-food' items	7 22	14 96	12 86	12 66	21 15	19 35	19 37	19 19	23 01	30 90	18 27	50 75	249 69
28. on 'all' items	33 91	62 79	54 19	49 14	73 38	61 78	61 05	54 98	61 09	70 48	47 19	91 89	721 87
29. no. of sample households	260	369	240	217	305	244	197	207	193	187	138	197	2754

no of sample villages = 1544 no of sample urban blocks = 1220

Based on the National Sample Survey (NSS) 10th Round, December 1955—May 1956, All-India (rural and urban) excluding Jammu & Kashmir.

Table A 1 1 *Index number of consumer expenditure per person for a period of 30 days by items of consumption: All India (Rural and Urban): 1955-56*

items	expenditure classes in rupees per person per month												
	0-8	8-11	11-13	13-15	15-18	18-21	21-24	24-28	28-34	34-43	43-55	55 & above	all classes
(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Index number of average expenditure per month													
1. foodgrains	53	71	89	96	105	115	125	129	132	141	152	211	100
2 sugar	18	39	49	71	82	102	127	151	205	222	235	173	100
3. milk & products	9	25	38	53	63	102	123	154	211	269	570	489	100
4. other food	36	55	69	81	97	104	127	142	167	177	219	364	100
5. total food	40	58	75	85	96	109	125	137	156	173	236	304	100
6. clothing	12	30	45	58	81	108	124	147	218	279	245	579	100
7. medical	2	21	26	44	63	86	107	119	195	281	402	907	100
8. others	25	38	45	56	71	89	105	138	160	243	286	744	100
9. non-food total	20	35	44	56	73	94	110	139	178	255	282	710	100
10 total (all items)	33	50	64	74	88	104	120	138	164	201	252	444	100
Index number of percentage of total expenditure													
11. foodgrains	158	141	139	129	120	110	104	94	80	70	61	48	100
12 sugar	53	78	77	95	94	98	106	110	126	110	114	106	100
13 milk & products	26	49	59	71	72	98	102	112	129	134	226	110	100
14 other food	108	109	108	108	110	100	106	103	102	88	87	82	100
15 food total	121	116	117	113	109	105	104	100	95	86	94	68	100
16 clothing	35	60	70	78	92	104	103	107	133	138	97	130	100
17. medical	7	42	40	59	72	83	89	86	120	140	160	204	100
18 others	76	75	71	75	81	86	87	100	98	121	113	168	100
19 non-food total	61	69	69	75	83	91	92	101	109	127	112	160	100
20 total	100	100	100	100	100	100	100	100	100	100	100	100	100
21. percentage of persons	14 01	17 31	11 74	9 14	11 55	8 21	7 04	5 53	5 17	4 85	2 59	2 86	100 00
22. cumulative percentage	14 01	31·32	43 06	52 20	63 75	71 96	79 00	84 53	89 70	94 55	71 14	100 00	—
23 size of households (persons)	112	111	118	104	100	95	93	84	93	93	68	70	100
24. no of households	12 53	15 59	9 92	8 83	11 51	8 68	7 59	6 08	6 16	5 22	3 79	4 10	100
25 no. of persons	14 01	17 31	11 74	9 14	11 55	8 21	7 04	5 53	5 17	4 85	2 59	2 86	100
Index number of total expenditure													
26. on 'food' items	5 65	10 13	8 75	7 73	11 07	8 99	8 83	7 58	8 06	8 38	6 12	8 71	100
27. on 'non-food' items	2 89	5 99	5 15	5 07	8 47	7 75	7 76	7 69	9 22	12 37	7 32	20 32	100
28. on 'all' items	4 70	8 70	7 51	6 81	10 16	8 56	8 46	7 62	8 46	9 76	6 54	12 72	100
29. no of sample households	260	369	240	217	305	244	197	207	193	187	138	197	2754

no of sample village = 1544, no of sample urban blocks = 1220

Based on the National Sample Survey (NSS). 10th Round, December 1955—May 1956, All-India (rural and urban) excluding Jammu & Kashmir.

9. The index numbers given in Table A.1 1 lines 11 to 19, show the change in percentages of expenditures (as distinguished from actual expenditure) on different items. It is seen that the percentage expenditure on foodgrains and other items of food decreases with rising expenditure level. The percentage expenditures on sugar, milk and milk-products, and clothing, however, continue to increase as expenditure increases, and the relative increase is highest in the case of medical expense.

Concentration curves for consumer expenditure

10 The question of equality or otherwise of the consumer expenditure can be studied in a different way in the form of what is called "concentration curves". Relevant data are given in Table A.1 2 and are also shown in a graphical form in curves B, C, and D, in the chart given on p 76. Consider the right hand side of the chart The horizontal scale at the bottom represents percentage of the population (beginning at the bottom with those having the lowest expenditure per person and finishing with those having the highest expenditure at the top) The vertical scale on the right hand side represents percentages of the total consumer expenditure, rising from zero to 100 percent at the top.

11. Consider the total expenditure, say, on all items and call this 100. If each person has an exactly equal share, then 5 percent of the population would have 5 percent of the total expenditure; 10 percent of the population would have 10 percent of the total expenditure and so on It is possible to draw this as a graph. Corresponding to a point 5 percent on the horizontal scale the value of the ordinate would be 5 percent; for 10 percent on the horizontal scale the corresponding value on the vertical scale would be 10 percent. The graph is obviously given by the straight line joining the "zero" point on both scales with the "100"-point on both scales which is the straight line inclined at 45° to the axis. This line represents a completely egalitarian distribution without any concentration.

12. The actual distribution or apportionment of expenditure is, however, not equal; and it would be of interest to plot the graph of the observed expenditure Relevant data are given in Table A.1 2, in which col. (1) shows the expenditure groups as in Tables A.1 0 and A 1 1 In this particular case the information is given separately for two sub-samples 1 and 2 based on different sets of sample villages and sample households It may be mentioned here that the estimates given in Tables A 1.0 and A 1 1 were obtained by combining the two sub-samples 1 and 2.

13. The sample villages and the sample households in each sub-sample were selected in accordance

Table A.1.2: *Cumulative percentage of expenditure on 'food', 'non-food', and 'all' items · all-India (Rural and urban) · 1955-56*

per capita expenditure classes in Rs	actual number of sample households		cumulative percentage of total number of persons		cumulative percentage of expenditure on					
					'food' items		'non-food' items		'all' items	
	S S 1	S S 2	S S 1	S S 2	S S 1	S S 2	S S 1	S S 2	S S 1	S S 2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
			.. .	. . ..	..cumulative percentage....				.. .	......
0— 8	135	125	13 84	14·18	5 64	5·66	2 82	2 96	4·67	4·73
8—11	181	188	31·52	31·12	16 15	15 43	8·60	9 15	13 55	13 26
11—13	122	118	43·62	42 50	25 37	23·74	13 80	14 25	21 38	20 45
13—15	115	102	52·65	51·74	33 16	31·41	18·89	19 31	28 23	27 21
15—18	153	152	64·17	63 33	44·38	42 30	27·56	27·59	38·57	37 20
18—21	131	113	73·61	70·32	55·06	49 66	36·32	34 37	48 59	44 36
21—24	89	108	79·36	78 63	62·29	60 03	42·97	43 19	55 62	54 19
24—28	104	103	85·93	83·14	71·32	66 22	52·37	49 24	64 78	60 33
28—34	91	102	90·28	89·12	77·81	75 80	60 63	59 37	71 88	70 10
34—43	98	89	95·31	93 79	86·66	83·73	73 64	71·14	82 17	79 36
43—55	60	78	97·08	97·19	90 83	91·73	79·27	80·07	86 85	87 69
55 & above	98	99	100·00	100·00	100 00	100·00	100 00	100·00	100 00	100 00
all classes	1377	1377								

no of sample villages: S S 1=772, S S 2=772. no of sample blocks: S S 1=610, S S 2=610.
Based on National Sample Survey (NSS): 10th Round, December 1955—May 1956, All India (rural and urban) excluding Jammu & Kashmir.

with a design of sampling based on the theory of probability. Each sub-sample covers the whole of India (rural and urban), and each sub-sample would supply valid estimates for every item under study. The two sub-samples are completely interpenetrating, and the results based on the two samples have equal validity and are comparable. The object of using two (or more) interpenetrating sub-samples can be briefly explained. As each sub-sample gives a valid estimate. a direct comparison of the results based on two (or more) sub-samples immediately supplies information on the consistency of the estimates If two (or more) sub-sample estimates are in good agreement, then it is possible to have confidence in the results. If the results diverge widely, then the results must be suspected. How this method works in practice would become clear as soon as the procedure for drawing the graphs is explained.

14 The number of sample households in the two sub-samples are given in cols (2) and (3) to show the size of samples but are not used in drawing the concentration curves Col (4) gives the accumulated percentages of persons in sub-sample 1, similar to the figures given in line 22 of Table A.1.0. Percentages for sub-sample 2 are given in col (5) The expenditure on, say, food items (or non-food items, or all items) is known for each expenditure group shown in col (1); and the total expenditure on food items for all expenditure groups taken together is also known. It is, therefore, possible to express the expenditure incurred in any particular group as a percentage of the expenditure incurred by all the groups In this way, each expenditure group, in each line of Table A 1.2 would have a figure giving its percentage share of the total expenditure on food (or non-food, or all) items These percentages can then be added successively from the bottom up, and would supply the 'cumulative percentage of expenditure', say, on food items shown in col (6). For example, the expenditure group '0-Rs 8' accounts for 5·64 percent of the total expenditure on food items. The two groups '0-Rs. 8' and 'Rs 8-11' together account for 16 15 percent of the total expenditure on food items and so on.

15. The cumulative percentages of persons in col (4) can be represented on the horizontal scale (at the bottom of the chart); and the corresponding cumulative percentage of expenditure can be represented on the vertical scale (on the right of the chart). The values given in the same line in cols (4) and (6) are plotted on the chart and are shown by the graph for sub-sample 1 of concentration curve B for expenditure on food items. A similar graph can be drawn for sub-sample 2 on the basis of each pair of figures given in the same line of cols (5) and (7) The two graphs for concentration curve B were drawn in this way The same procedure was followed in the case of expenditure on non-food items by plotting the figures given in cols (4) and (8) for sub-sample 1, and the figures in cols (5) and (9) for sub-sample 2; these are shown in the two graphs of concentration curve C. For expenditure on all items, the figures in cols. (4) and (10) for sub-sample 1, and figures in cols. (5) and (11) for sub-sample 2 are plotted to give the two graphs of concentration curve D

16. It is of interest to examine the three sets of double graphs of B, C, and D. Consider the two graphs of curve B, each of which gives an equally valid sample representation of the concentration curve for expenditure on food. They diverge to some extent but not too much. We may, therefore infer that the 'true' concentration curve B for expenditure on food items lies somewhere in the neighbourhood of the pair of graphs for sub-samples 1 and 2. Also, the divergence between this pair of graphs supplies some idea of the margin of errors of sampling. In the same way, we can locate approximately (and always subject to some margin of errors of sampling) the position of concentration curve C for expenditure on non-food items, and the position of concentration curve D for expenditure on all items of consumption.

17. The divergence between the concentration curve B, on one hand, and the concentration curve D, on the other hand, can be directly seen on the chart to be much greater than the divergence between the pair of graphs for the two sub-samples of curve B or of curve D. From this we may infer that the two concentration curves B and D are significantly different in the statistical sense. Looking at all the three pairs of graphs it can be inferred that the three concentration curves B, C and D are all different. It has been possible to make this inference in this very simple manner, because we have been able to use a pair of graphs (based respectively on sub-samples 1 and 2) for each of the three concentration curves B, C and D.[1]

18 We may now examine the concentration curve or the figures given in Table A 1.2 to understand the implications. For sub-sample 1, the lowest group '0 to Rs. 8' has a percentage share of population of 13·84 percent, in col (4); but its share of expenditure on food items is only 5·64 percent, in col (6); and the share of non-food expenditure

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[1] When a particular number or quantity (as distinguished from a curve, as in the present case) is estimated, the margin of error can be calculated with considerable accuracy on results based on two or more interpenetrating samples. The rule is extremely simple: for a set of 2, 3, 4, 5, 6,. . *k* interpenetrating samples the probability would be respectively

1/2, 3/4, 7/8, 15/16, 31/32 $(2^{K-1}-1)/2^{K-1}$

and the 'true' value of the parameter lies between the two extreme estimates based on the interpenetrating samples. This method is being used in the Indian Statistical Institute since 1937.

is still less and only 2 82 percent, in col (8); the share of expenditure on all items is 4 67 percent, in col (10), and naturally falls between the other two. The position can be ascertained for other groups or for any percentage of the population directly from the graph. It would be seen the lower the concentration curve at the beginning, the lower will be the share of the poorer households.

19 It will be noticed that expenditure on food is more egalitarian than the expenditure on all items, while expenditure on non-food items deviates most from equality This can be seen clearly from the curves B, C and D on the chart. The further a concentration curve lies towards the lower right-hand corner of the chart, the greater is its deviation from the egalitarian distribution shown by the straight line inclined at 45° to the axis The more intense the concentration, the greater would be the advantage enjoyed by a few rich men over a very large number of poor people. Concentration curves thus give a simple visual picture of the non-equality of the distribution.

Concentration curve for land holdings

20. It is, of course possible to draw concentration curves for distributions other than that of expenditure. The case of holdings of land by households is of great interest Some relevant data are given in Table A.2.0 based on a special survey of land-holdings carried out in the NSS: 8th round: July 1954-March 1955 covering the whole rural area of India. In this survey 12 interpenetrating sub-samples were used information for 4 of which was collected by the NSS (which is a Central agency) and information for the remaining 8 sub-samples was collected by respective State Governments in the form of two groups of samples called State-I and State-II, each consisting of 4 sub-samples. The information is given in Table A 2.0 separately for

Table A.2.0. *Percentage of households (excluding those of size less than 0 10 acre) below specified size of ownership holding and the corresponding percentage of area owned All India (Rural) · 1953-54*

Specified size of ownership holdings	Number of sample households			Cumulative percentage of					
				Total number of households			Area owned		
	Cetral	State I	State II	Cetral	State I	State II	Central	State I	State II
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. 0·10 - 0·50 acre	1,107	1,210	1,043	9 49	10·94	9·47	0·37	0 40	0·33
2. upto 1 00 ,,	1,099	1,095	1,075	18·95	20·58	18 82	1 29	1 37	1 23
3. ,, 1 50 ,,	1,060	996	1,012	27·38	28 90	27 34	2·70	2 80	2 61
4. ,, 2 50 ,,	1,656	1,578	1,596	40·21	41·33	40 75	6 17	6 20	6 10
5 ,, 5·00 ,,	2,856	2,805	2,622	61 24	61·97	60 68	16·53	16 65	15 54
6 ,, 7 50 ,,	1,825	1,848	1,722	73 73	73 51	72 60	26 99	26 55	25 20
7 ,, 10·00 ,,	1,164	1,265	1,241	80 77	80·60	80 05	35 34	35 17	33 73
8. ,, 15 00 ,,	2,311	2,495	2,486	88 25	88 69	81 71	47 93	48 93	46 06
9. ,, 20·00 ,,	1,368	1,337	1,337	92·42	92 56	91 78	57 83	58 28	55 36
10. ,, 25·00 ,,	1,038	964	1,021	94 56	94·80	94 11	64 38	65·23	62 18
11 ,, 30 00 ,,	675	629	740	96 13	96·15	95·76	70·29	70·38	68 18
12. ,, 40·00 ,,	757	693	847	97·77	97·77	97 56	77 98	78·19	76 32
13. ,, 50·00 ,,	396	392	414	98·61	98·64	98·48	83·10	83 58	81 39
14. ,, 75·00 ,,	413	395	464	99 48	99·44	99·44	80·16	90·37	89 48
15. ,, 100·00 ,,	127	134	136	99·73	99 71	99·70	92·98	93 64	92·40
16 ,, 250·00 ,,	131	134	128	99·97	99·99	99 97	97 60	99·10	97 69
17. ,, 500·00 ,,	14	6	18	99 99	100·00	100 00	98·62	99 68	99 01
18 above 500·00 ,,	6	1	4	100·00	100·00	100 00	100·00	100 00	100 00
19. Total	18,003	17,977	17,906						
20. Sample villages	1,410	1,422	1,383						

Based on the National Sample Survey: 8th Round, July 1954—March 1955. Information for the Central sample was collected by an agency of the Government of India and for the State samples by the respective State Governments. The Central, State-I, and State-II samples are each based on four interpenetrating samples; and all 12 samples also form, of course, an interpenetrating net work of samples covering the rural area.

3 groups of samples: Central, State-I and State-II.

21. Information was obtained about the size in acres of the total holdings of land owned by each household. The households were then classified in groups by size of holding, such as, owning '0·10 to 0·50 acre;' owning '0'50 to 1 00 acre' and so on. The number of households in each group and also the total area of land held by each group were then calculated; and these were expressed as percentage of the total number of households and of the total area of land owned by all households. The next step was adding up the percentages by successive groups to give the 'cumulative percentage of household' and the 'cumulative percentage of total area of land owned by households,' These figures are given for the Central sample in cols (5) and (8) respectively of Table A.2.0; for State-I sample in cols (6) and (9) respectively, and for State-II sample in cols. (7) and (10) respectively. These three sets of values were then drawn on the chart in the form of the three graphs of concentration curve E, at the extreme lower right-hand corner of the chart.

22 The number of sample households is given in cols (2), (3) and (4) which show that the size of the sample was much larger in the case of the survey of land-holdings compared to the survey of household expenditure. Each of the Central, State-I and State-II samples had about 18,000 sample households compared to only 1377 sample households in sub-samples 1 and 2 in the case of household expenditure. It is of interest to note that the three graphs of curve E lie very close to one another (and are almost indistinguishable). no doubt. due to the large size of the samples Comparing the graphs of curve E with the graphs of B, C and D. it is seen that the margin of errors of sampling is much smaller in the case of curve E. The size of samples in the case of landholdings would seem to be quite adequate.

23. It should be mentioned that in the present case only those households have been included which own more than 0·10 acre of land in order to exclude landless labour and households who practically do not own any land. The most important point to be noted is that the concentration of land-holdings is far greater than the concentration of expenditure on non-food items of consumption. The distribution of land-holdings is thus far more unequal than the distribution of consumer expenditure The curves B, C, D and E give a clear idea of the inequality in the level of living and in the ownership of land in India at the present time.

Employment and unemployment

24. Table A 3.1 shows the position regarding the labour force, employment and unemployment based on the 9th Round of the National Sample Survey (NSS)· May-August 1955. Estimated numbers in million are given for each category in cols. (2), (3) and (4) for rural and urban areas, and all-India respectively. The corresponding percentage of the total are shown in cols (5), (6) and (7) The first portion A gives the basic information Consider the all-India figures given in col (4) and corresponding percentages in col (7). It is seen from line 1 that the total estimated population (on the basis of the National Sample Survey) was 382 4 million in 1955, and from line 3 that the labour force consisted of 162·6 million persons (or 42 5 percent of the population, as shown in col (7), line 3) who were at work or seeking work at the time of the survey. Within the labour-force itself 160·4 million were gainfully occupied (line 5) and 2·24 million were "unemployed" (line 4) in accordance with the concept of "unemployment" used in industrially advanced countries.

25 For various reasons, it is known that the concept of unemployment used in the advanced countries is not suitable in the case of under-developed countries in which most of the people work in household enterprises and agriculture They are never "unemployed" in the technical sense, but may often have to sit idle for lack of gainful work. The figures for "unemployed" given in line 4 are not, therefore, adequate. A better picture can be obtained, if consideration is given to the amount of time a person is available for work or is actually engaged in gainful work This has been sought to be done in Part B of the table. Three different approaches were used

26 Information was collected on how many more hours a person was available for work per week and the replies were classified in groups of "available from 1 to 8 hours per week," "from 8 to 14 hours per week," etc , (that is, by units of 1 hour per day per week), shown in lines 6 to 13. Those who are available for work for more than 29 hours per week (that is, who can accept work for more than 4 hours per day for 7 days) are either practically unemployed or are sitting idle for half the week or more Their number would come to 11·7 million [col (4), line 9]. This is perhaps a lower limit of effective unemployment.

27. Information about hours of work per week is given (in an accumulated form) in lines 14 to 20. It would be seen that the number of persons working less than 8 hours per week was 20·9 million and their position was practically the same as that of the unemployed. The number of persons working less than 29 hours per week or 4 hours per day was as large as 44 8 million [col (4), line 16].

28. A third approach was to enquire how many days a person was engaged in gainful work during 30 days preceding the day of interview. The information is given in the form of accumulated totals in lines 21 to 26. The number of persons working less than 10 days out of 30 days, or less than one-third of the month, was 39·2 million [col (4), line 22]. This is broadly consistent with the figure 44 8 million given in the previous paragraph.

29. There is, however, a big gap between estimates of the number of unemployed persons based on B (1) the hours per week available for additional work and B (2) the hours of work per week. A special enquiry carried out in the NSS: 7th Round, October 1953-March 1954 had given some interesting information on this point. The number of persons working part-time was obtained as 47·2 million corresponding roughly to 44·8 million persons who worked 28 hours or less per week as given in col (4), line 16 of Table A.3.1. The enquiry in the 7th Round brought out that among them

Table A.3.1: *Status of economic activity and gainful employment Rural, Urban and all-India*

	estimated number of persons in million			percentage of total		
	rural	urban	all-India	rural	urban	all-India
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A Distribution of population by status of economic activity[1]						
1. total population	316·1	66·3	382·4	100·0	100·0	100·0
2. outside labour force	176·4	43·4	219·8	55·8	65·6	57·5
3. in labour force	139·7	22·9	162·6	44·2	34·5	42·5
4. unemployed	0·92	1·32	2·24	0·29	1·99	0·59
5. gainfully employed	138·8	21·6	160·4	43·9	32·6	41·9
B Distribution of gainfully employed persons by period of work						
(1) *hours available for additional work per week*[2]						
6. above 70 hours	0·38	0·04	0·42	0·28	0·20	0·26
7. ,, 56 ,,	1·2	0·11	1·3	0·85	0·51	0·81
8. ,, 42 ,,	6·1	0·7	6·8	4·4	3·3	4·2
9. ,, 28 ,,	10·4	1·3	11·7	7·4	6·2	7·3
10. ,, 14 ,,	17·6	2·5	20·1	12·7	11·6	12·5
11. ,, 7 ,,	22·1	3·2	25·3	15·9	15·0	15·8
12. ,, 1 hour	24·3	3·4	27·7	17·5	15·7	17·3
13. nil	138·8	21·6	160·4	100·0	100·0	100·0
(2) *hours of work per week*[2]						
14. 7 hours or less	18·9	2·0	20·9	13·6	9·2	13·0
15. 14 ,,	24·3	2·6	26·9	17·5	12·1	16·8
16. 28 ,,	40·2	4·6	44·8	29·0	21·5	27·9
17. 42 ,,	64·3	8·5	72·8	46·3	39·5	45·4
18. 56 ,,	109·7	17·2	126·9	79·0	79·4	79·1
19. 70 ,,	133·4	20·3	153·7	96·1	93·9	95·8
20. all	138·8	21·6	160·4	100·0	100·0	100·0
(3) *days of work per 30 days*[3]						
21. less than 5 days	28·2	1·6	29·8	30·2	7·2	18·6
22. ,, ,, 10 ,,	37·2	2·1	39·2	26·7	9·6	24·4
23. ,, ,, 15 ,,	50·1	3·2	53·3	36·1	14·6	33·2
24. ,, ,, 20 ,,	62·5	4·6	67·1	45·0	21·1	41·8
25. ,, ,, 25 ,,	78·3	8·2	86·5	56·4	38·0	53·9
26. ,, ,, 30 ,,	138·8	21·6	160·4	100·0	100·0	100·0

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[1] Based on the National Sample Survey (NSS): 9th Round, May-August 1955; growth of population calculated on the Census 1941-1951 rate of 1·32 per cent per annum.

[2] Percentages in cols (5) to (7) and lines (1) to (20) based on NSS: 9th Round, May-August 1955, sub-samples 1 and 2 only, consisting of 8,037 rural and 16,703 urban sample households.

[3] Percentages in cols(5) to (7) and lines (21) to (26) based on NSS: 5th and 6th Rounds, December 1952-August 1953, consisting of 12,976 rural and 5,670 urban sample households.

10·4 million (22 percent of the total) were working part-time partly on account of ill-health of the worker and partly because of illness in his household. Also, 23·4 million persons (or roughly half) were working a part of the time for reasons of an economic nature, such as lack of demand for their labour, lack of tools and raw materials, slack and off season, etc.; and 13·4 million persons gave other reasons. It would seem from the above discussion that at least 23 million persons, who were working part-time for reasons of an economic nature, can be considered as severely "underemployed."

30. It is clear that the volume of underemployment is very great indeed in India. It is, however, difficult to set up precise definitions and standards for unemployment and underemployment especially in rural areas and in household and small scale enterprises and in the case of self-employed persons. The actual number would depend entirely on where the line is to be drawn between employment and underemployment.

31. Table 3.2 gives information on the distribution of gainfully employed persons by industries and by economic sectors (public, large scale, private household, etc). From col (9) it is seen that out of a total number of gainfully employed persons of 160·38 million, 119·76 or nearly 120 million work in agriculture, forestry, livestock, etc The total number engaged in manufacturing industries is only 17·54 million. out of which also only 3·47 million are engaged in modern large scale industries. Trade and commerce with 5·84 million and service with 5·13 million come next in order of importance.

32. From col (2), bottom line, it is seen that 7·26 million persons are employed in the public sector, that is under the Central and State Governments, Municipalities, and other public authorities; and from the total of col (3) that 5·65 million are employed in private large scale enterprises. These two taken together, 12·91 million persons have employment of the type familiar in industrially advanced countries, and in their case it is probably possible to specify fairly well whether a person is employed or unemployed in the sense in which "unemployment" is defined in advanced countries.

33. The private small scale sector has 146·61 million [col (7), bottom line], out of which 115·23 million are household labour (col. 4). They may be fully or only partly engaged in work but can almost never be "unemployed" in the technical sense The structure of employment clearly shows the backwardness of the Indian economy.

34. Table A 3.3 shows the incidence of "unemployment" among educated persons defined as matriculates or having higher educational qualifications. The concept of "unemployment" used is the same as that used in the advanced countries and is known to be much too restricted and hence unsuitable for underdeveloped countries. However,

Table A.3.2.: *Gainfully employed persons by industries; all-India: 1955*

industry	public	private large-scale	private small-scale				not recorded	total
			household labour	hired labour	domestic service	sub-total (4)+(5)+(6)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				million persons				
1. agriculture, forestry, livestock, fishing and hunting	0·41	0·93	93·23	24·76	0·00	117·99	0·51	119·84
2. mining and quarrying	0·04	0·39	0·01	0·08	—	0·09	0·00	0·52
3. manufacturing	0·44	3·47	11·38	2·10	0·00	13·48	0·16	17·55
4. construction	0·26	0·22	0·66	0·85	0·00	1·51	0·01	2·00
5. electricity, gas, water, sanitation	0·16	0·01	0·09	0·00	—	0·09	0·01	0·27
6. trade and commerce	0·10	0·22	4·78	0·72	0·00	5·50	0·02	5·84
7. service	2·65	0·14	1·07	0·49	0·77	2·33	0·01	5·13
8. transport and communication	1·47	0·14	1·03	0·24	0·00	1·27	0·03	2·91
9. not specified above and not recorded	1·73	0·13	2·98	0·67	0·70	4·35	0·11	6·32
10. total	7·26	5·65	115·23	29·91	1·47	146·61	0·86	160·38

Based on the National Sample Survey (NSS): 9th Round: May-August 1955, sub-samples 1 and 2 only consisting of 8,027 rural and 16,703 urban households.

Table A.3.3 *Distribution of total population and unemployed persons by education class: Rural, Urban and All India: 1955*

education class	rural		urban		all-India		percentage of unemployed		
	total	un-employed	total	un-employed	total	un-employed	rural	urban	all-India
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
			million persons					percentage .	
1. below matriculate	314·70	0·76	62·70	1·01	377·40	1·77	0·24	1·60	0·47
2 matriculate	1·10		2·40		3·50				
3. intermediate	0·19		0·65		0·84				
4 graduate and above	0·13		0·57		0·70				
5 sub-total (2—4)	1·42	0·16	3·62	0·31	5·04	0·47	11·42	8·59	9·40
6. total	316·12	0·92	66·32	1·32	382·44	2·24	0·29	1·99	0·59

Based on the National Sample Survey: 9th Round, May-August 1955, sub-samples 1 and 2 only, consisting of 8,03·7 rural and 16,703 urban sample households. Growth of populaion calculated on the basis of the Census 1941-51 rate of 1·32 percent per annum.

using this strict definition of unemployment, it is of interest to observe [from col (7), line 5] that there were about 0·47 million or 4·7 lakhs unemployed in 1955 out of a total of 5 million or 50 lakhs of educated persons altogether. Taking into consideration the facts that about 4 lakhs of candidates matriculated in 1955 and that the number is steadily increasing, it can be easily imagined how very difficult the problem of unemployment among educated persons would become in future, unless there is rapid economic development.

General and professional education

35. Table A.3.4 shows the number of persons passing different examinations in India each year from 1950 to 1955 based on information collected by the Planning Commission. There is no doubt that general education is increasing quite fast. In most cases numbers have more than doubled in five years since 1950. The number of matriculates was over 4 lakhs in 1955 which represented about 1050 matriculates per million of the population. The number of first graduates was about 57,000 or about 150 per million which is comparable with an out-turn of about 20,000 graduates in the UK with a population of 51 million or 392 per million. A comparison can also be made on the basis of literate persons. The number of literates in India in 1955 was about 63·2 million (all ages below 5 are omitted in calculations relating to literacy). The number of matriculates in 1955 was thus about 5,300 per million literates; and the number of first graduates was about 900 per million literates. In the UK the number of persons of age 5 years or more was about 44 million and this would be also the number of literates (because of universal literacy) and is comparable to 63 million literates in India. On the basis of an out-turn of about 20.000 graduates per year in the UK, the number would work out at about 450 graduates per million literates. The proportion of graduates in India in relation to literates (900) would this seem to be double that of the UK (450). This supplies some interesting information on social differentials in education.

Table A.3.4: *General and professional Education: All India 1950-55*

qualification	number of persons qualifying in						index-number: 1951=100
	1950	1951	1952	1953	1954	1955	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
General education							
1. Matriculation	1,89,184	2,41,143	2,61,059	3,34,760	3,97,005	4,00,014	166
2. Intermediate	59,283	72,685	77,836	89,021	1,04,851	1,26,476	174
.1 Arts	41,652	47,013	52,373	59,703	71,640	86,741	185
.2 Science	17,631	25,672	25,463	29,318	33,211	39,735	155
3. First degree	28,745	32,238	36,136	40,033	50,178	57,051	177
.1 Arts	19,212	21,251	24,965	27,491	35,773	40,444	190
.2 Science	9,533	10,987	11,171	12,542	14,405	16,607	151
4. Master's degree	5,581	7,138	7,734	7,855	9,777	11,013	154
.1 Arts	4,503	5,729	6,054	6,161	7,709	8,802	154
.2 Science	1,078	1,409	1,680	1,694	2,068	2,211	157
5. Doctorate	115	146	164	123	280	324	222
.1 D Phil (junior)	56	136	159	115	269	n.a.	(198)
.2 DSc (senior)	59	10	5	8	11	n.a.	(110)
6. total	2,82,908	3,53,350	3,82,929	4,71,792	5,62,091	5,94,878	168
Engineering and technology							
7. Certificate	566	14,189	13,604	17,418	15,718	18,588	131
8. Diploma	784	1,547	2,871	2,575	3,148	3,774	244
9. First degree	1,923	2,189	2,510	3,046	3,520	3,583	164
10. Master's degree	50	66	82	69	211	144	218
11. total	3,323	17,991	19,067	23,108	22,597	26,089	145
Medical science							
12. Diploma	50	117	120	267	—	—	—
13. First degree	2,017	1,624	1,985	2,146	3,131	—	(193)
14. Master's degree	19	256	261	350	693	—	(271)
15. Doctorate	52	54	55	63	48	—	(89)
16 total	2,138	2,051	2,421	2,826	3,872	—	(200)
Agriculture							
17. Certificates	459	783	1,120	982	999	1,510	193
18. Diploma	585	661	352	691	563	778	118
19. First degree	1,067	1,118	984	914	1.004	971	87
20. Master's degree	146	151	209	190	198	193	128
21. total	2,257	2,713	2,665	2,777	2,764	3,452	127
Veterinary science							
22. Diploma	62	34	37	—	—	—	—
23. First degree	112	242	237	252	298	300	124
24. Master's degree	—	—	—	—	135	147	—
25. total	174	276	274	252	433	447	124

Notes: (1) Index-numbers within brackets are for year 1954.
(2) Source of information: Division of Perspective Planning, Planning Commission.

NEXT STEPS IN PLANNING

P C MAHALANOBIS

(delivered at New Delhi, 1959)

Introduction

India adopted planning for economic development with the initiation of the First Five Year Plan in 1951. At this stage, the plan was essentially a list of projects without any clear unity of purpose. A sense of strategy began to develop and certain broad aims were formulated in advance in 1954 for the preparation of a draft frame for the Second Five Year Plan. It was agreed that attempts must be made to get India out of the fear of unemployment in ten years or as soon as possible, to lay sound foundations for a continuing improvement in the level of living, that is of the national income; and also to bring about greater equality of opportunities.

In 1955 India accepted socialism as the goal of economic policy. The Second Five Year Plan took a long term view of economic development over a period of 10 or 15 years or more, and adopted a basic strategy for this purpose which involved a crucial change in the outlook. Three years have nearly passed after the initiation of the Second Plan in April 1956 There have been many gains and some set-backs; and much experience has been gathered. We must now prepare our mind for the Third Five Year Plan which will have to be started in about two years. It is, therefore, appropriate that we should now consider the next steps in planning.

Review of Industrial Development

Before doing this it will be useful to consider previous developments in India in the context of the history of industrialization of the more advanced countries of the world. The industrial revolution started about two hundred years ago in the United Kingdom, the USA and countries of Western Europe where science and technology were highly developed. At first there was expansion of the manufacture of textiles and other consumer goods. The use of steel for industrial purposes started less than a hundred years ago. The world production[1] of steel was less than one million metric tons in 1870, and reached 4 4 m tons in 1880 and 28 m tons in 1900. In 1870 UK and Germany were producing about 200,000 tons per year and USA and Russia had just started. By 1880 UK and USA reached 1 3 m ton and Germany reached this level in 1885, and France in 1895. These countries were already industrialized and had a high level of living indicated by per capita income of from 400 to 600 US dollars per person per year (at current dollars for 1955 and 1956) the time they reached the level of production of one million ton of steel per year. Health and education also were fairly well developed with the number of physicians ranging between 3 6 and 16 3 per ten thousand of population. Developments were fairly rapid from this time and USA reached 4 3 m tons in 1890, Germany 4 m tons in 1895, UK 5 m tons in 1900 and France 4·7 m tons in 1913. During this period there was some further expansion of health, education and research which was broadly in accordance with the previous trend.[1] An output of 4 or 5 million tons of steel per year usually makes a turning point in industrial progress. At this level it becomes possible to establish comprehensive manufacturing complexes of steel, heavy machine building and heavy electrical industries, and chemical engineering.

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[1] Data on production of steel are given in Table 3 in the Appendix.

[1] Information on certain characteristics of development is given for selected countries in Table 1 in the Appendix.

Japan had started producing steel just before the First World War and reached one million ton in 1923 when Japan's per capita national income was still quite low and only 125 US dollars. Health and education in Japan were, however, as highly developed as in the advanced countries of Europe and America. Japan reached 4·9 m tons in 1935, that is in 12 years. It is important to note that modernization in Japan had started about 90 years ago with the Meiji Restoration with deliberate emphasis on health, education, scientific research and industrialization. Japan, for example, had made primary education free and compulsory before UK

Russia had reached the production of about one million ton of steel as early as 1895 but was quite backward in education and health with 1 6 physicians per ten thousand of population and with only 3 percent of the population in primary schools. Owing to war, revolution and civil war, production in USSR had decreased to 0 6 m ton in 1923, but recovered to 4 9 m tons in 1929 by which time education and health had also developed in a remarkable manner approaching conditions prevailing in the more advanced countries at corresponding epoch. China started very recently with 0 6 m ton of steel in 1950 and rapidly reached 5 m tons in 1956 and 10 m tons in 1958.

Until recently industrial developments in India were taking place rather slowly and in a somewhat imitative way of the earlier history of industrial growth in Europe and America in which we can distinguish four layers or phases. On the top or the surface comes consumer goods which can be established fairly quickly with the help of imported machinery. The second layer is the production of electricity, steel and other metals; this is highly capital intensive and requires large imports of machinery and also an appreciable amount of time. Next is the manufacture of heavy machines, heavy electrical apparatus and chemical engineering (for the production of industrial raw materials). This usually requires a much longer time but, once established, would enable a large part of the capital and producer goods being manufactured out of domestic resources. Even more basic is the expansion of health, education, science, and of scientific and technical manpower which takes practically a generation to mature.

Following the above pattern only upto the first phase of consumer goods, India had become the second biggest producer of textiles in the world and had also developed the manufacture of other consumer goods without however establishing the basic industries like metals, heavy machine building and heavy electricals In fact, in India the production of steel had remained basically at a little above the level of one million ton after nearly half a century of the beginning of the industry, although the country has very large resources of iron ore of the best quality. The economy was developing only very slowly on the basis of immediate demands and supplies without any long range view. Also, there was comparatively little development of health, education, and science in relation to the size of the country and its population.

Gains in the Second Five Year Plan

There were important gains in the Second Five Year Plan which marked a radical break with the old way of thinking. It was realised that unemployment and poverty can be cured only through rapid industrialization. It was not enough to expand the production of textiles and consumer goods. It was necessary to increase the supply of energy and of machinery and tools of production to create more employment. It was realised that the only way to do this in a big country like India was to establish, as rapidly as possible, the basic steel, heavy machine building, and heavy electrical industries and chemical engineering. This would make it possible to produce capital and producer goods of all kinds and thus expand industrial investments increasingly out of domestic resources This is the only way to secure increasing supplies of machinery and energy, with which we can create more employment and also can give the workers more machinery so that the total production in the country can rise rapidly.

In India the highest priority must be given to the establishment and expansion of the basic industries Large investments in the basic industries would, of course, give rise to an increasing demand for food, cloth and other consumer goods. In India it is possible and desirable to meet this demand by setting idle hands to work in the traditional way or in small scale industries to produce consumer goods and other necessities as much as possible. This would also create much employment all over the country.

It was appreciated that, in India the production of an agricultural surplus is the key to industrialization It is not only essential to grow enough food and fibres for our own requirements but it is also necessary to produce a surplus in the form of either industrial or food crops. In India agriculture and manufacturing industries are completely interlocked Economic progress depends on the advance of both Advance of one step in agriculture would supply food and raw materials for advance of one step in manufacturing industries which again, in its turn, would speed up irrigation and increase the supply of fertilizers and pesticides and help in the promotion of scientific research, which would lead to further advances in agriculture. The importance of the scattered or diffused phase of production, both in agriculture and in traditional and small scale industries, was broadly appreciated. It is also being increasingly realised that land reform and the organization of village co-operatives are urgent and essential needs for increasing agricultural production.

The Second Five Year Plan accepted the above strategy of economic development in a general way. It was decided to expand steel production to about 5 million tons; to give high priority to atomic energy; to establish a heavy machine building industry and the manufacture of heavy electricals; and also to develop prospecting for oil exploration and to establish oil refineries of our own. India would be now able to start developing large manufacturing complexes.

There were, however, gaps and set-backs also An acute shortage of foreign currency occurred in the very first year of the Second Plan which in my opinion was not inescapable but was largely due to lack of adequate tools and instruments of planning and also partly to lack of proper appreciation of the strategy of the Second Plan. The shortage of foreign currency created great difficulties. I discussed this question in my Anniversary Address last year The remedy is in our own hands because in India we can manufacture capital and producer goods increasingly out of our own domestic resources, once the basic industries are established and developed Therefore the only radical cure of the shortage of foreign currency would be by building up the basic industries as rapidly as possible.

Foreign aid, especially in the form of long-term loans for capital goods and technical personnel, would be of critical importance at the stage of what PMS Blackett has called "assisted take of" in industrialization. Indefinite reliance on foreign loans is neither possible nor desirable A continuing stream of short-term financial loans from abroad would not be of much help in the long run and may make the position worse. The chief source of capital formation must be domestic savings Fortunately, the need of raising more resources is admitted and gradually action is being taken in this regard. One notable advance was the acceptance of the principle of an expenditure tax together with a tax on wealth.

In the highly developed countries of the West, taxes on commodities are usually looked upon as "regressive" as being a burden on the poor. Public enterprises are also expected to be run on a no-loss no-profit basis. Fortunately our outlook is changing and it is being realised that in an underdeveloped country like India excise and customs duties, purchase tax on commodities or a levy on services would be convenient and adaptable methods to raise resources. It is also agreed in principle that public enterprises should earn and contribute increasing returns for purposes of national development.

It is encouraging that the question of scientific and technical manpower is receiving increasing attention. The subject is being studied at a technical level in the Division of Perspective Planning in the Planning Commission. A Standing Committee of the Cabinet has been set up for manpower; and administrative units have been established in the Central Government and in the States.

Weaknesses in planning

The Second Plan, no doubt, has been a great step in advance. It has set production forces in motion which cannot possibly be reversed without disaster. There are, however, serious gaps and weaknesses.

Review of industrialization has shown that there is a close connexion between economic development and progress in health and education. (Some relevant data for both developed and underdeveloped countries have been given in Table 2 in the Appendix). In West Europe and America there was simultaneous progress of industries and health, education and science. In Russia, before the first World War, the production of steel had reached 5 million tons but there was little progress in health and education; and there was revolution. In USSR, China and other socialized countries and also in Japan great emphasis was and is being given to progress in health, education and science *pari passu* with industrialization India would soon reach the critical level of steel production of 5 million tons but is still backward in health, education and science.

Before considering these three points in some detail I shall refer to another disturbing aspect of the present situation, the steady increase in unemployment

Increase in unemployment

We do not yet have in India any regular reporting of unemployment. Some indications are however, available from trends in the number of applicants in the Labour Exchange Registers in India for which some data are given in Tables 4 and 5 in the Appendix. It is disturbing to note that the total number of persons registering in these Exchanges had more than doubled in five years between January 1953 and December 1957. It is also worth noting that the Labour Exchanges can find employment for only a very few, and the average number of applicants for each notified vacancy increased steadily from 23.3 in 1953, year by year, to 33 in 1957. Also as all notified vacancies were not filled by applicants recommended by the Labour Exchanges, the number of applicants for each effective placement was nearly 40 in 1947 and had steadily increased to nearly 51 in 1957. That is, the Labour Exchanges can find employment for only two persons or less out of every *hundred* applicants, on an average. This is not a criticism of Labour Exchanges but simply an indication of the heavy back-log of unemployment.

This back-log differs in different occupational categories for which some information is given in Table 4. The ratio of applicants to effective placements increased in practically all categories except in "others". The greatest relative increase occurred among those seeking "education," "clerical" and "unskilled" jobs. In

1957 there was only one effective placement for 36 applicants seeking educational posts; and one for 75 seeking clerical or unskilled jobs It is clear that the size of the second plan was not big enough to absorb the fresh seekers of employment who joined the labour force through the growth of population. A much bigger plan is essential to get rid of the fear of unemployment.

In my Anniversary Address last year I gave some information on unemployment and underemployment obtained through the National Sample Survey I explained the difficulties of measuring underemployment and stated that there was scarcely any doubt that 10 or 12 million persons in India were unemployed or severely underemployed and that this figure might rise to even 25 or 30 million if consideration extended to those who were sitting idle for more than half of their normal working time I had drawn attention to the fact that about 10 per cent of educated persons (matriculates and above) were probably unemployed, and that this number was likely to rise. The evidence from Labour Exchanges would seem broadly to corroborate this.

It is clear that the Second Five Year Plan has not succeeded in absorbing, in sufficiently large numbers, the new seekers of employment. It is also likely that unemployment is continuing to increase among educated persons especially in urban areas This is a disturbing sign The only conclusion to be drawn is that the Third Five Year Plan must be much bigger in size than the Second Five Year Plan It would be remembered that in the Second Five Year Plan it was visualized that net investments should reach Rs. 9,900 crores in the Third Plan. Let us round off the figure, and adopt Rs. 10,000 crores as the target for investment in the Third Five Year Plan.

Health

Health, education and research have indeed a dual role. These are no doubt significant constituents of the level of living and, in this sense, are fruits of national development. On the other hand, advance of health, education and research are of basic importance in bringing about industrial and social progress I shall first consider health.

In India at present there are about 70,000 physicians of whom a little less that a half are trained at the University level and about 37,000 are licentiates with four-year training in junior medical schools. The distribution of doctors by level and qualification and state of residence in 1954 are given in Table 6. The number of doctors in India as a whole is about 176 per million of population or one physician for about 5,700 persons on an average The number however varies widely from one state to another, from over 600 per million (or one for 25,000) in Rajasthan and Manipur What is, however, much more serious is that most of the doctors reside in urban areas; and the total number of doctors residing in rural areas (with a population of about 330 million) may be below 10,000 that is, only one doctor for 30,000 persons or more on an average In some rural areas it is known that there is only one qualified doctor for 50,000 or 100,000 persons

An important committee on health and medical care (popularly known as the Bhore Committee from the name of its Chairman) stated in the foreword to its report submitted in 1946 that "*no individual should fail to secure adequate medical care because of inability to pay for it*". This Committee had prepared a long-term programme most of which still remains unimplemented.

There is no difference of opinion regarding the desirability of providing medical care to all who need it In India, unfortunately, in some respects we are still at the stage of a somewhat superficial imitation of the most advanced countries of Europe and America. Junior medical schools were

percent of households	cumulative percentage of expenditure on			
	medical services		medicine	
	USA[1] 1950	India[2] 1955	India[2] 1952	India[3] 1955
(1)	(2)	(3)	(4)	(5)
	percent share of expenditure*			
bottom 10 per cent	5	0·1	1	1
(lower half) 50 „	37	6	9	8
top 10 „	19	64	45	56

[1] *USA* 1950: Studies on Consumer Expenditure, 1950, Vol VIII (University of Pennsylvania)
[2] *India* 1952: National Sample Survey: 4th Round; April-September 1952; All-India (Urban).
[3] *India* 1955 National Sample Survey: 9th Round, May-November 1955 All-India (Rural)

**Note*: The classification is by size of income of households for the USA 1950 data, by size of expenditure of households for India 1952 data; and by size of expenditure of persons for India 1955 data The American and Indian results are therefore not comparable in a completely rigorous way but the broad picture is clear. The expenditure on both medicine and medical services are far more concentrated in India showing that it is only the very few rich who can afford to pay for medicine and medical services. The two series for India 1955 have been, however, classified in the same way; and show that the distribution of expenditure on medical services is relatively more concentrated, that is, medical services are even more scarce than medicine in rural areas of India

abolished after independence on the view that our countrymen cannot be allowed to have anything less than the best And yet to provide a sufficient number of university trained doctors and adequate hospital and medical services upto the standard of the rich countries of the world is absolutely impossible at present

Doctors and drugs are both extremely scarce in India Doctor's fees and the price of drugs are also high which keep these beyond the reach of most people The extreme inequality in the distribution of expenditure on medicine and medical services can be appreciated from the relative share of expenditure on these items, shown below (and also from the Chart in the Appendix) for the bottom ten per cent, the lower half, and the top ten per cent of all households.

The above Table gives some similar figures for urban areas in USA in 1950. Looking at the first line of the table it is seen that the bottom ten per cent of American households share five per cent of the total expenditure on medical services incurred by all households, the corresponding share of the bottom ten per cent of rural households in India is negligibly small and only about 0·1 per cent From the second line it is noticed that the lower half of American households share 37 per cent of the total expenditure while the Indian households share only 6 per cent of the total We may also look at the top. Ten per cent of the households at the top in America take a share of 19 per cent of the total while the corresponding Indian households at the top have 64 per cent or nearly two-thirds of the total expenditure on medical services. The position is almost as bad in the case of medicine. In India the lower half of rural households share only 8 per cent of the total expenditure on drugs[1], the corresponding figure for urban households being 9 per cent.

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[1] Similar figures for the distribution of consumer expenditure on other items like foodgrains, all food items, cloth, sugar, education, and medical services are given in Tables 12, 13 and 14 in the Appendix.

It may be pointed out, at this stage, that in countries with free and universal health services like UK and USSR every person, in principle, receives essential medical services and medicine. In both countries, as private medical practice is permitted and drugs can be purchased in the market, some medical expenditure may be incurred by the rich on their own, but there is no discrimination between the rich and the poor so far as the medical care is available to the poor either free of charge or at a very small cost.

I should like to make a few suggestions for consideration for the Third Five Year Plan Firstly, I think it would be wise to reintroduce training extending over, say, 3 years for a junior type of doctor or auxiliary health workers who would be prepared to serve in villages for a modest allowance of say something like Rs 1,000 per year with permission for private practice within certain limits The training cost would be possibly one-fourth or one-fifth of that of a fully qualified doctor The pay or allowance would also be one-fifth or even less of the pay which would have to be given to a university level doctor The cost of training and maintaining a junior doctor may be thus five times cheaper

The organisation of medical teaching at a junior level would also be feasible on a much larger scale than at the university level. There are about 400 district hospitals, which, with some additional facilities, can serve as training centres for junior doctors; and which, on an average, may be able to turn out 25 trained persons each per year which would supply 10,000 junior doctors per year after the scheme is in full operation. This would make it possible to have, one junior doctor for a group of ten villages in roughly half a million villages in eight or ten years One fully qualified doctor may be placed in charge of about five junior doctors; and should be able to give some attention to the more difficult cases.

The cost of providing hospital and other health services would also have to be brought to a level which the country can afford The cost of construction standard and specifications which would be appropriate for a poor country like India; and, secondly, by improving the efficiency of public construction It is also necessary to develop rapidly the manufacture of drugs and medical goods, and also to establish factories for the manufacture of machinery for this purpose There, is of course, need of more systematic research for a fuller exploitation of our own natural resources for medical and health purposes.

Finally, it seems to me it would be very wise to initiate a truly national health service, even if this be in a skeletal form, during the third plan period The emphasis in the first instance should be on establishing a large number of small village units which would provide essential medical and health service to the villages and also serve as family planning centres. This is the only way in which there would be any real chance of promoting birth-control effectively This is a matter of great importance and urgency

Education

India is backward in education generally Some comparative information is given in Table 7 for selected countries In most advanced countries there is practically no illiteracy, and in China also the position is improving rapidly India is still far off from universal and compulsory primary education. In India the number of illiterates (including both males and females) was 83 5 per cent of the population according to the Census of 1951 The National Sample Survey indicated that there was only a slight reduction of illiteracy to 82 5 per cent of the population as a whole in 1955 The number of students in primary schools in India was about 60 per 1000 of population in 1956 against 87 in China in 1955, 144 in Japan in 1956, 125 in USSR, and 154 in USA.

The position is quite different at the

secondary level. India had 23 students per 1000 of population at the secondary level in 1956 which was three times higher than the corresponding figure 7·4 in China in 1955. Also, the Indian figure does not compare too badly with 38 in USSR in 1957-58 or 48 in USA in 1955. The number of students in the university and equivalent levels in India is remarkably high with a rate of 1·8 per 1000 of population which can compare favourably with 0 5 in China, 1·6 in UK, or 2·5 in West Germany and 3 5 in France.

This structural difference in education comes out even more clearly if we adopt the number of primary students as the base for comparison For every thousand students in the primary stage, India had about 384 at the secondary level in 1956 which was much higher than the corresponding proportion of 84 in China, and also higher than the proportions in France (264), USSR (300), and USA (312). The number of students in the univerity and equivalent levels per thousand students in the primary level is also very high in India and was about 30 against 5 or 6 in China, 15 in UK, 26 in West Germany, 31 in France and 47 in Japan Only USA and USSR have higher proportions.

The above comparisons bring out several points. India is weakest at the primary level and is far behind China and all advanced countries of the world. India has a much stronger position at the secondary level on a population basis. If however, the number of primary students is used as the base for comparison then India has proportionately larger numbers in the secondary schools than most advanced countries of the world including USA and USSR. At the university and equivalent levels, also, India has a higher proportion of students than UK and has a proportion of the same order as Germany or France on the basis broadly of both population and of the number of students at the primary level. It is important to note that higher education in India has been expanding quite rapidly in recent years. Some relevant information is given in Table 8 which shows the enrolment of students by level of education, subjects, and sex in 1950-51 and 1956-57. It can be seen from this table that the total enrolment at higher levels (from intermediate to post-graduate and equivalent courses) was about 400,000 in 1951 and increased to about 780,000 in 1956-57, that is, the number had almost doubled in six years It can be further noted that the largest increase had taken place at the intermediate level. On the whole, there was relatively greater expansion in arts, commerce and law compared to science and technology including medicine and veterinaries.

The out-turn of qualified persons in India, at intermediate and higher levels also showed a large increase and, more or less, kept pace with the increase in enrolment Relevant data for the period 1951-56 are given in Table 9 in the Appendix There was, however, a good deal of wastage. On the whole, only about half the candidates who appeared at the examinations at the higher (university and equivalent) levels succeeded in passing these examinations. The proportion of successful candidates was the lowest at the intermediate stage (between 42 and 46 percent). Relevant figures on number and percentage of successful candidates are given in Table 10. Large percentages of failure give rise to much frustration and to much waste of time, money and effort.

Some interesting information can be obtained by examining the number of students in higher courses in proportion to the number of matriculates for which relevant statistics are given in Table 11. It can be noticed from this table that for every 10,000 students who matriculated in 1952, about 6,750 had enrolled for courses at the intermediate level in 1952-53 out of whom about 4,400 succeeded in passing the appropriate examinations at this level in 1954. The enrolment at the degree levels was 3,319 in 1954-55, and the number receiving degrees two years later in 1956 was 2,364. The enrolment in post-graduate courses in 1956-57 was 1,552. It may be noted that for every 10,000 candidates who had matriculated in 1952 only 2,920 or less than 30 percent took up courses in science and technical subjects at the intermediate level; and less than 12 per cent proceeded with courses in science, technology, agriculture, medicine and veterinary at the degree stage. Finally, only 156 or less than two percent took post-graduate courses in science and technology The educational base is poor for a rapid expansion of scientific and technical personnel at higher levels.

Higher education in India developed to a great extent in a somewhat imitative way on the British pattern Social and economic conditions are however entirely different in India. Academic ideals which are realisable in the UK sometimes necessarily degenerate into superficial imitation and window dressing. Indian colleges often have very large numbers of students who are not adequately prepared for higher education. University and college teachers are poorly paid and are often obliged to do a good deal of part-time outside work Classes are very big, and library and laboratory facilities are often poor. It is not surprising that conditions of work in the universities are not entirely satisfactory.

In the advanced countries of the world there are usually good opportunities for productive employment for the students who come out of universities and other higher institutions. In India the position is entirely different. Only a very small proportion receive vocational or professional training. A very large number receive what is called general education which does not make them fit to undertake any particular productive work. As I have already mentioned, unemployment among educated persons in India is increasing. This is creating a great deal of frustration and discontent. The greatest weakness in India is the lack of an organic relation between the system of education and national needs for economic development.

A radical reform of the educational system is a most urgent next step in planning. It is necessary, to turn out an increasing number of suitably trained personnel to meet the increasing demands of an expanding economy. The first thing in education must therefore be to give appropriate vocational and professional training which would make graduates of higher educational institutions qualified to undertake productive work of one kind or another This is not in any way incompatible with what is called general culture. In fact, the two can very well go together. Dr Zakir Hussain in his Patel Memorial Lectures has recently given a most illuminating exposition of this theme

Planning for socialism

At this stage it is desirable to recall that in India socialism has been declared to be the goal of economic policy It is quite proper not to try to give any rigid definition. And yet it is essential to have some clear understanding in this matter as a guide to action In USSR, China and other countries in which socialism of one form or another has been already established, planning is considered to be an essential requirement for economic and social progress; and the aims and objectives of planning are settled in accordance with the principles of socialism in the accepted form. In other words planning in the socialized countries is an instrument of socialism. In India the position is different Socialism has been accepted as the aim but has not yet been established. It is, therefore, important to examine the relation between planning and socialism.

Many different ideas have been associated with the concept of socialism in different countries and at different times. I shall select three ideas which have special relevance to our problems. The first is rapid economic development through full utilization of the resources of the country. This was the object for which planning was established in India and should continue to receive full attention. The second idea I should like to mention is removing progressively large disparities in wealth, income and power, and the third is fostering equality of opportunities of all kinds for all the people of India.

The distribution of wealth, income and privileges is extremely unequal in India. The number of persons who pay income-tax is of the order of five lakhs or half a million.[1] Multiplying by five, (which is the average number of persons per household) the total number of persons in families paying income-tax would be about 2 5 million out of a population of nearly 400 million or appreciably less than one percent The class which has some money and influence in India is thus extremely small and possibly forms not more than one or two percent of the whole population Facilities for education being both scarce and expensive, higher education is probably almost a monopoly of this privileged class at the top. The inequality in the distribution of expenditure on educational services can be seen from the accompanying Chart and Table 14 in the Appendix. The bottom 10 percent of rural households in India have a share of less than one percent of the total educational expenditure and the lower half (50 percent) of households shared 11 percent only, while the top 10 percent have as much as 36 percent. Many poor people do not get even the opportunity to learn how to read and write. Many who complete the primary stage cannot join secondary schools; many who complete the secondary stage are unable to go to institutions of higher education on account of poverty. The same process of selection, on the basis of the income of the parents, continues at all levels of higher education. Finally it is only the rich people who can send their children abroad for higher training and education

Inequalities in medical care result in a larger number of deaths among the poor people. Inequalities in educational opportunities have a deeper and more pervasive effect. It is true that some extremely able students succeed in securing scholarships up to the highest level but their number is very small. By and large, it is rich people who have the opportunity of giving their children the type of education required for posts of influence and responsibility in the country By and large, those having such training are selected for posts of responsibility on the strength of their higher educational qualifications. In this way the power and privileges of a small group of people at the top tend to be not only preserved but strengthened. In both public services and organized private enterprizes practically all posts of influence and power are held by persons belonging to the same small privileged class This has created an influential group of people who naturally desire to maintain their privileged position and power. During the British period many of the influential people were not enthusiastic about the political change because they were afraid of losing their own privileges. In the same way it is not surprising that there are people in India today who are not enthusiastic about a rapid economic progress out of a similar fear of losing their privileges and power It is necessary to remove barriers to educational opportunities to overcome such difficulties. This is the only way in which a sound foundation can be laid for democracy and socialism in India.

Educational reform

The only real remedy is to make education entirely free and also to ensure that no deserving student would be deprived of educational opportunities on account of poverty. It is no doubt necessary and desirable to do this at all levels of education; but it may be too difficult a task to undertake immediately. As a first step, it is suggested, that this reform should be carried through at the university and equivalent levels during the period of the Third Five Year Plan This would call for several types of action Firstly, all fees at the university level would have to be abolished by increasing the direct contribution from Government by an equal amount. Secondly, enough financial assistance would have to be provided by Government to enable every deserving student being maintained during the whole period of his study in higher educational institutions Thirdly, selection for admission to higher education would have to be made entirely on merit Fourthly, it would be desirable to institute evening classes, correspondence courses, and external examinations on a large scale to provide opportunities for higher education to those who are unable to attend the day-classes and also to maintain a policy of open door as a safeguard against rigidities and defects which may develop within a strictly controlled system of admissions Finally, it would be desirable to initiate a scheme for constructive work for the nation which would be obligatory for one or two years for all students who are admitted to higher educational institutions or who graduate from such institutions This is not the occasion to give any detailed scheme but it may be useful briefly to consider some of the implications of the above proposals

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[1] The actual number depends on the level of income at which income-tax becomes chargeable; this level has fluctuated between Rs. 2,500 and Rs. 4,200 per year in recent years.

We have seen that total enrolment in higher education had nearly doubled in six years and was about 780,000 in 1956-57 The direct expenditure on higher education was about Rs 293 million (Rs 29 3 crores), out of which about 42 percent or Rs 120 million (Rs 12 crores) came from students' fees.[1] The number of students during the Third Plan period would no doubt be higher. If expansion continued at about the same rate, the number in the middle of the Third Plan Period may reach a million and a half It may not be however necessary or desirable to allow such an increase in future, and we may provisionally accept a target of one million students in higher education in the Third Plan but also keep in mind a million and a half For one million students, the Government grant in lieu of fees would come to about Rs 16 crores, and for a million and a half to about Rs 44 crores per year at current rates and prices

As regards financial assistance for maintenance, at the rate of Rs 300 or Rs 400 per year per student on an average, the cost would come to Rs 30 or Rs 40 crores per year for one million students I have used average figures because it would be quite reasonable to adopt something like a "means test" so that the amount of the stipend would depend on what assistance the parent would need to maintain the student without any strain Secondly, stipends of a larger amount may be offered as incentive to attract students to science and technology or other suitable subjects and also to post-graduate course The total cost may be of the order of Rs 50 or Rs 60 crores per year If the Third Plan succeeds in raising the national income by five percent per year (and this is about the lowest safe limit) then the additional income generated would be at least of the order of Rs 600 crores per year or more out of which there should not be any difficulty in providing the above expenditure.[2]

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[1] Compared to a fee income of 42 percent of the total expenditure in India the income from fees at the university level is less than 11 percent in UK and is about 8 percent in the land-grant institutions many of which are the great State universities of USA.

[2] It is appropriate at this stage to point out that the proposals to abolish all fees in higher education and to award maintenance stipends out of government funds would merely involve a redistribution of the national income; and should not, in principle, cause any additional strain on the economy as a whole. It would be necessary, of course, for Government to raise the required amount through additional taxation or in other ways. But, in principle, the amount which was being spent by the parents of the students would be set free and would be available for either savings or consumption. In other words, there would be no additional call on physical resources.

Selection for admissions on merit is indeed a formidable task, but I venture to think it is not beyond our capacity if we call science to our aid. The objects of the admission test must be clearly defined, and attempts must be made to maintain uniform standards throughout the country I shall make a few suggestions to serve as a basis for further discussions It may be desirable to try to assess such aspects of the candidate's qualification, for example, as (*a*) his content of knowledge in appropriate subjects, (*b*) his ability to search and compile relevant information from books and written materials, (*c*) his capacity to organize his knowledge and convey his ideas in a clear way in a written form, or (*d*) his skill in manual or technical work or ability to make scientific observations or experiments. These are all amenable to assessment on a more or less objective basis. For example, modern objective tests, in which a candidate has only to indicate his choice between different alternative answers, can be used in testing knowledge in a standardised manner throughout the country. The ability to compile and collect information from given books and materials can also be standardised at different levels of difficulty The ability to convey in a coherent form his knowledge and ideas can be tested by asking the candidate to prepare written notes on the basis of material given to him or to be collected by him from given books and papers. His power of expression can be tested by the usual type of free essay for which several hours can be allotted. Some kind of practical work or experiments can also be made a part of the examination

I should like to mention that, in my opinion, modern statistical methods can be very used effectively to select a required number of questions for any particular paper out of a given "universe of questions" in a random manner and at the same time to maintain assigned levels of difficulty and subject coverage within prescribed limits with objective certainty. This would have two advantages It would enable uniform standards being maintained throughout the country and from year to year. I would also permit almost infinite variations in the content of individual question papers so that copying from an answer book can be made practically impossible. Furthermore, with the help of modern electronic computers it would be possible to mark the objective type of papers very quickly and accurately.

I may also explain that the test for admission need not be one single examination but may very well be different examinations for different groups of subjects For each examination it would be, however, necessary to maintain as uniform standards as possible over the whole country. To maintain parity or equivalence of standards between different examinations would be technically a more difficult task However in principle, it is not absolutely necessary that the quality of the candidates should be the same in all subjects If there is greater competition in certain subjects it is likely that such subjects would attract candidates of a higher quality on an average This need not be prevented.

One great advantage of the proposed system would be that it would be possible to regulate admissions to particular subjects in accordance with social needs and opportunities of employment which are likely to be available to the students after graduation. In this way admission to higher education would be geared to future requirements of trained manpower.

It would be of advantage in many ways to institute evening classes, correspondence courses and external examinations to offer fuller opportunities for higher education. Correspondence courses are being used very extensively in USSR apparently with great success; and it would be possible to take advantage of Soviet experience. Arrangements may have to be made for laboratory or other institutional work for prescribed periods or during vacations. All this would, of course, call for much organisational effort and experimentation which would offer scope for much employment of persons with higher education. A standard system of external examinations (including practical work or tests as necessary) would keep the door open for every one and would be a safeguard against abuses developing within a closed system.

National service

If the State undertakes to make education available at its own expense to all deserving students then it would be entirely proper to ask the students to undertake productive and constructive work for the country for one or two years The maintenance stipend would be continued or can be increased in suitable cases during this period In many countries of the world a period of service in the armed forces is compulsory In India, instead of conscripted service in the defence forces, we may think of a period of obligatory service in peace camps or in a peace force for constructive work.

It would be probably convenient to ask the students to put in their prescribed period of service immediately after their graduation. This would supply every year a large number of highly trained persons who would be able to undertake productive work of various kinds. This would be direct gain to the nation. For example, it would be possible to use a large number of such students to do teaching work at different levels all over the country. The medical graduates can help in bringing medical care to the villages. For the trainee himself it would be a valuable period of apprenticeship training, something like the "internee" work in hospitals by medical graduates, and would be of help in their finding employment suited to their training and aptitudes. The most valuable aspect of the peace camps or peace forces, if I may use this phrase, would be the bringing together of young persons from widely differing types of families in a comradeship of active work for the country. This would be an effective way of promoting the spirit of democracy. Although I have spoken of students joining the peace camps or the peace force after graduation from higher institutions of education it is also possible to have "world schools", as Dr Zakir Hussain has called them, for students before they come to the University In USSR a new policy has been adopted of asking all students to work for at least two years from the age of 15 before they are admitted to institutions of higher education. Various possibilities are thus open The really important point is to accept the principle that a prescribed period of service in a peace force for say two years at some stage or other would be an obligatory requirement for all educated persons.

Science and research

The importance of science and technology for national development has been recognised in India, in principle, since independence. It cannot be said, however, that progress has been entirely adequate or satisfactory. There is urgent need of levels. Much improvement is also needed in the organization of research There is no time to make a comprehensive review, and I shall make some brief observations on some selected aspects of the problem.

Science is developing so fast that it is becoming increasingly difficult for teaching to keep pace with the advancement of knowledge. J D Bernal has recently pointed out that:

"With a rapidly growing civilization, the young will year by year have more to know and also, will be required, by the new demands made on them, to know more.... Something must be done to simplify and reduce the amount of learning at every stage.... In the past with some reason, teaching was considered to be the passing on of known and established truths from one generation to the next.... But clearly, in a civilization where the whole basis of knowledge is expected to change several times in a generation, the passing on of established knowledge becomes palpably inadequate and, also, from its ever increasing bulk, impossible.

It is lucky if most of what is taught is true, or supposed to be true, at the time it is taught. It is certain that it will no longer be considered true by the time those who are taught are half-way through their lives. What is needed, therefore, is a different and lightened content of education. The emphasis will be on discovery rather than knowledge. It will be, not so much the passing on the established truths, as showing the way to criticize and discover new truths, in other words, the active part of the scientific method."[1]

Some serious thinking has been going on for some time in the Indian Statistical Institute on organizing an integrated course of science teaching in which emphasis would be given to develop the student's skill in observation, counting, measurement, logical analysis and interpretation of the facts and the design of new experiments to test the working hypothesis One single set of observations and experiments may cover different branches of science, which, it is hoped, may give an integrated outlook on scientific method. It is no longer possible to have encyclopaedic coverage of knowledge. The only possibility is to try to make an intensive and integrated study which would touch particular aspects of different branches of science. I have no time to elaborate these thoughts but it seems to me that it will be well worth making some experiments in this direction.

It is essential to spread the teaching of science extensively at the school level without which it will be never possible to secure a sound foundation for advancement of science in India. Sir Alexander Fleck, in his presidential address to the British Association for the Advancement of Science in 1958 mentioned that in USSR children from 11 to 17 years devote 46 percent of their school time to science subjects. I am aware that it is not possible to approach this level immediately in India but we should keep some such target in view. Teaching of science, both in schools and universities, deserves serious attention by senior scientists.

As regards the organization of science in its wider sense, I have on other occasions pointed out that our own National Institute of Sciences is not very active Our Institute is supposed to have responsibility of advising Government on scientific matters. In practice there is very little activity of this kind This I think is partly due to lack of clear ideas regarding what should be the proper function of scientific societies in the changing conditions of the present time; and also, I am sorry to say, partly due to lack of a sense of responsibility on our own part. I have made some suggestions in my Annual Review in 1958 and need not say anything more on the present occasion.

I am a strong advocate of the public sector but this, in my view, does not mean concentrating all activities in government departments On the contrary, in the scientific field, I think it is essential to build up and maintain truly independent scientific organizations which would be in a position to offer advice and constructive criticisms and suggestions to Government I have already mentioned that we ourselves have not been sufficiently serious regarding our own responsibilities. But I also think that the time has come for Government to give serious attention to the future structure of scientific organization and research in India not only within government but for the country as a whole.

If I may put it in this way, the solution does not lie in officialising all scientific activities but gradually to make the scientific organizations truly functional by transferring to them real responsibilities and entrusting them with fruitful activities. The advancement of science requires proper recognition of scientists in the structure of society as a whole. In this connexion I may remind you that Sir

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[1] J D Bernal; *World Without War*, 1958, pp. 197-198.

Alexander Fleck has given a quotation from an administrator which went on record that "the place of the expert is not in the saddle but as the assistant and the adviser. The scientist must be on tap, not on top." I can only say that the future of India depends on reversing the dictum of the administrator and recognising that the scientist must be on top and not merely on tap I have a deep conviction that scientist must supply the leadership in national development. It is necessary that they should take the initiative.

Appendix

STATISTICAL TABLES

Table 1: *Some characteristics of development for selected countries*

country	year	population in million (10^6)	steel production in million metric tons per year	per capita national income US dollars	physicians per ten thousand of population	school children percent of population
(1)	(2)	(3)	(4)	(5)	(6)	(7)
			level of one million ton of steel per year			
1. USA	1880	50	1·3	635	16·3	19
2. UK	1880	31	1·3	385	6·6	12
3. Germany	1885	48	1·2	340	3·6	15
4. France	1895	39	0·9	485	3·9	14
5. Russia	1895	105	0·9	95	1·6	3
6. Japan	1923	56	1·0	125	7·7	17
7. India	1955-56	384	1·3	60	1·7	0·8
			level of 4 or 5 million tons of steel per year			
1. USA	1890	63	4·3	735	15·9	20
2. UK	1900	38	5·0	560	8·8	16
3. Germany	1895	54	4·0	430	4·0	17
4. France	1913	39	4·7	550	5·3	14
5. USSR	1929	147	4·9	95	4·3	8
6. Japan	1935	69	4·9	195	8·4	17
7. China	1956	608	4·5	70	1·2	1·6
8. India	1960-61	408	4·3	72	2·1	1·0

Compiled by the Planning Division, Indian Statistical Institute.

Notes on Table 1

1. Figures of steel output are taken from Woytinsky and Woytinsky. *World Population and Production,* for all countries except China and India. Chinese and Indian figures relate to finished steel and are respectively taken from *China Today,* 25 August, 1957, and *Second Five Year Plan, 1956* (India).

2. For USA, UK and Japan, population figures are taken from the Statistical Abstracts of the respective countries relating to different years. Figures for Germany and France are obtained by interpolation from data given by Woytinsky and Woytinsky. Russian data relating to 1895 are obtained in the same manner while the figure for 1926 is from the *National Economy of USSR.* Chinese data are from unpublished official Chinese sources; and Indian data from the *Second Five Year Plan*

3. Data on number of school children for USA, Germany, UK and Russia are taken from the *Encyclopaedia of Social Reform* and Mulhall, *Dictionary of Statistics.* French data relating to 1895 is from the *Statistical Year Book: National Institute of Statistical and Economic Studies,* France, while for 1912-13, are from the *International Year Book of Statistics, 1920.* Data for USSR and India are from sources given in (2). The figure for Japan is based on the *Satistical Abstract of Japan, 1933* and the *UN Statistical Year Book* The Chinese figure is from the *Report on Fulfilment of the National Economic Plan in 1955.*

4. The US figures for doctors are from the *Historical Statistics of USA* while those for UK are from the *Professions* by Carr-Saunders and Wilson. French data are obtained from Woytinsky and Woytinsky. The German and Russian figures are from Mulhall, *Dictionary of Statistics* and Woytinsky and Woytinsky, *World Population and Production* while the figure for USSR is from *40 years of Soviet Power.* The Japanese figures are from the *Statistical Abstract of Japan, 1933* and the *UN Statistical Year Book, 1949-50.* Indian and Chinese data are from sources indicated in (3).

5. National income figures are roughly dimensional and are obtained from certain estimates at current dollars for 1955 or 1956 carried backward by index numbers of real per capita income. Some of these current estimates were considered in the Science and National Planning, *Sankhyā,* September, 1958

The index numbers used for USA are taken from data given in the *Economic Report of the President, 1957*; and the "Long-term Change in the National Income of the USA since 1870" by Simon Kuznets, (*Income and Wealth,* Series II) The German figure is adjusted by series available in the *Statistics of National Income and Expenditure,* (UN Statistical Papers, Series H), and the "Long-term Growth of National Income in Germany" by P. Jostock, (*Income and Wealth,* Series V). For the UK estimates, use has been made of data given by Prest, National Income of the *UK,* (*Economic Journal,* March 1948); Phyllis Dean, Contemporary Estimates of National Income   Nineteenth Century (*Economic History Review,* Vol 8, No 3 and Vol 9, No. 3); the *Statistics of National Income and Expenditure* (*UN*) and *UN Sattistical Year Book* The French figures are obtained on the basis of UN sources indicated above and a series of real output per working person given in Colin Clark: *Conditions of Economic Progress.* The figure for Japan is adjusted by data given in the *Japanese Statistical Year Book, 1957* while Chinese and Indian data relating to current period are taken from official sources.

Table 2: *Population, national income, production of steel and electricity, and number of physicians and primary school students by countries and groups of countries about 1955-56*

countries	population in millions (10^6)	national income in US dollar billion (10^9)	production		per capita			physicians per ten thousand of population	primary school pupils per thousand of population
			crude steel in million (10^6) metric tons	electricity billion (10^9) kwh	national income in US dollar	production			
						crude steel (kg)	electricity (kwh)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. United States of America	165	341	106	629	2030	642	3812	13·2	158
2. United Kingdom	50	46	20	94	900	394	1846	16·7	108
3. Developed (sub-total)[1]	450	566	191	1107	1292	436	2527	11·5	132
4. USSR	200	200	45	170	1000	226	850	14·9	65
5. China	620	44	3	12	72	4·8	20	1·2	87
6. Socialized (sub-total)[2]	900	278	63	298	317	72	340	5·9	90
7. Japan	90	21	10	65	230	105	724	10·5	144
8. Medium (sub-total)[3]	350	86	13	120	259	38	360	7·3	116
9. India	380	23	2	8	61	4·5	21	1·8	54
10. Underdeveloped (sub-total) excluding China	900	71	2	25	80	2	28	1·4	65
11. Underdeveloped including China[4]	1500	114	5	37	76	3	25	1·3	74
12. World [3+6+8+10] total	2600	1002	269	1550	397	106	611	5·5	92

Compiled by the Planning Division, Indian Statistical Institute. Population and other figures have been rounded off dimensionally.

[1] Includes developed countries in North America, Europe, Australia (as in list A).

[2] Includes all socialized countries (as in list B).

[3] Includes Japan and medium developed countries in Europe and Latin America (as in list C)

[4] Includes underdeveloped countries in Asia and Africa (as in list D).

Notes on Table 2

List A (developed countries):

(1) Australia, (2) Austria, (3) Belgium, (4) Canada, (5) Denmark, (6) France, (7) Federal Republic of Germany, (8) Finland, (9) Iceland, (10) Italy, (11) Luxembourg, (12) Netherlands, (13) New Zealand, (14) Norway, (15) Sweden, (16) Switzerland, (17) South Africa, (18) UK, (19) USA.

List B (socialized countries).

(1) Albania, (2) Bulgaria, (3) Czechosclovakia, (4) China, (5) German Democratic Republic, (6) Hungary, (7) Poland, (8) Rumania, (9) USSR, (10) Yugoslavia.

List C (medium developed countries):

(1) Argentina, (2) Bolivia, (3) Brazil, (4) Costa Rica, (5) Cuba, (6) Chile, (7) Columbia, (8) Dominican Republic, (9) El-salvador, (10) Ecuador, (11) Greece, (12) Guatemala, (13) Haiti, (14) Honduras, (15) Ireland, (16) Japan, (17) Jamaica, (18) Mexico, (19) Portugal, (20) Paraguay, (21) Peru, (22) Panama, (23) Puerto Rico, (24) Spain, (25) Turkey, (26) Uruguay, (27) Venezuela

List D (underdeveloped countries):

(1) Afghanistan, (2) Algeria, (3) Angola, (4) Burma, (5) Belgian Congo, (6) China, (7) Ceylon, (8) Cameroon, (9) Egypt, (10) Ethiopea, (11) French West Africa, (12) Ghana, (13) Hongkong, (14) India, (15) Indonesia, (16) Iran, (17) Iraq, (18) Isreal, (19) Kenya, (20) Lebanon, (21) Liberia, (22) Malay, (23) Morocco, (24) Mauritious, (25) Mozambique, (26) Madagascar, (27) Nigeria, (28) Pakistan, (29) Philippines, (30) Rhodesia and Nyasaland, (31) Saudi Arabia, (32) South Korea, (33) Syria, (34) Thailand, (35) Taiwan, (36) Tunisia, (37) Tanganayika, (38) Uganda, (39) Vietnam, (40) Yemen.

Sources:

Columns (2), (4), (5), (9) and (10) are from the *UN Statistical Year Book, 1956*

The Chinese population figure is taken from statistics prepared by the State Statistical Bureau of the People's Republic of China (in Chinese). The Chinese figures for physicians and primary school students are from the statistics prepared by the State Statistical Bureau of the People's Republic of China.

The USSR figures for physicians and primary school students are from the data supplied by the Central Board of Statistics of the USSR.

The method of estimation of national income figures is explained generally in *Sankhyā*, Vol 20 Parts 1 and 2, "Science and National Planning".

Table 3: *Output of crude steel in million metric tons[1] for world and selected countries*

Year	World[2]	United Kingdom	United States	Germany	USSR	Japan[6]	China	India
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1870	0 7	0·2	f[3]	0 2	f			
1880	4 4	1·3	1·3	0 7	0 3			
1890	12·4	3 6	4·3	2 2	0 4			
1900	28 3	5 0	10·4	6 6	2 2			
1910	60 5	6·5	26·5	13·7	3·5			
1913	76 5	7·8	31·8	18 9	4 8	0 2		f
1918	78·6	9 7	45·2	15 0	0·4	0 8		0 2
1923	78 5	8 6	45·7	6 3	0·6	1·0		0 2
1929	120·5	9 8	57·3	16 2	4 9	2 3		0 6
1932	50·7	5 3	13 9	5 7	5 9	2·4		0 6[10]
1939	135 6	13·4	47·9	22·4	17·6	6·7	0 5	1·1
1940	142 9	13 2	60 8	19 0	18·3	6 9	0 6	1·3
1944	152·1	12 3	81 3	18 0	13 9	5 9	0 9[7]	1·4
1945	113 3	12·0	72 3	0 3	12 3	2 1	n a	1 4
1950	188·7	16 6	87 8	12 1[4]	27 3	4 8	0 2[8]	1 5
1955	269·1	20·1	106 2	21 3	45 3	9 4	2 9	1·7
1956	282 6	21 0	104 5	23 2	48 6[5]	11 1	4 5[9]	1 8

[1] one metric ton = 1·1023 short tons

[2] Excludes China up to 1932 and 1944-50.

[3] f = less than 100,000 tons

[4] West Germany from 1950

[5] USSR 1957 and 1958 figures are 51 and 55 million metric tons respectively.

[6] Includes Korea up to 1932

[7] Relates to 1943

[8] Relates to 1949

[9] China 1957 and 1958 figures are 5 3 and 11 million metric tons respectively

[10] Relates to 1932-33

Compiled by the Planning Division, Indian Statistical Institute, from

(*a*) Woytinsky and Woytinsky: *World Population and Production Trends and Outlook* (New York, 1953).
(*b*) *United Nations Statistical Year Book, 1957.*
(*c*) D G Zhimerin *Economy of the Soviet Union, Past and Present* (Moscow, 1958)
(*d*) *News and Views from the Soviet Union* (USSR Embassy, New Delhi, 18 December, 1958)
(*e*) *China Today* 25 September 1958, 10 January 1959
(*f*) *Report on Fulfilment of the National Economic Plan of the People's Republic of China in* 1955 (with Statistical Summary).
(*g*) Sastry *A Statistical Study of Indias's Industrial Development*
(*h*) *Statistical Abstract,* India 1927-28 to 1936-37

Table 4: *Increase in live number on labour exchange registers in India in 5 years: 1953-57*

occupational category	number on live-register at end of month		increase in five years		monthly average of effective placements		ratio of applicants to effective placements[1]	
	January 1953 (131)	December 1957 (181)	number	percent	1953	1957		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. industrial supervisory	4,317	5,929	1,612	37·3	180	171	24·0	34·7
2 skilled and semiskilled	46,539	71,508	24,969	53·7	2,247	1,910	20·7	37·4
3. educational	6,625	40,246	33,621	507·5	401	1,117	16·5	36·0
4. clerical	113,424	267,757	154,333	136·1	2,006	3,594	56·5	74·5
5. domestic service	13,987	32,018	18,031	128·9	938	1,141	14·9	28·1
6. unskilled	221,761	460,639	238,878	107·7	8,452	6,178	26·2	74·6
7. others	27,775	44,002	16,227	58·4	1,230	1,958	22·6	22·5
8. all categories	434,428	922,099	487,671	112·3	154,54	16,069	28·1	57·4

[1] That is, col (8) =col (2)/col (6); and col (9) =col (3)/col (7)

Table 5: *Number on live register and number of vacancies and replacements: labour exchanges in India, 1953-57*

all categories	year				
	1953	1954	1955	1956	1957
(1)	(2)	(3)	(4)	(5)	(6)
1. monthly average of effective placements	15,454	13,538	14,145	15,821	16,069
2. monthly average of vacancies notified	21,392	19,990	23,377	24,718	24,766
3. monthly average on Live Register	477,575	562,319	647,109	749,099	816,280
4. number of applicants per vacancy (row 3÷row 2)	22·3	28·1	27·7	30·3	33·0
5. number of applicants per placement (row 3÷row 1)	30·9	41·5	45·7	47·3	50·8

Compiled in the Indian Statistical Institute from "A Study of Trends in the Number of Employment Seekers in the Year 1953-57." (Ministry of Labour & Employment, DGR & E, September 1958).

Table 6: *Distribution of doctors per million population by level of qualifications and state of residence in 1954*

states	population 1954 (million)	number of doctors			doctors per million (10^6) population			index with West Bengal = 100
		graduate and post-graduate	licentiate	all	graduate and post-graduate	licentiate	all	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1 Andhra	32·65	2,025	1,908	3,933	62	58	120	19·8
2 Assam	9·59	403	2,281	2,684	42	238	280	46·3
3. Bihar	40·07	1,762	3,302	5,064	44	82	126	20·8
4. Bombay	51·15	6,928	6,044	12,972	135	118	253	41·8
5. Jammu & Kashmir	4·54	32	42	74	7	9	16	2·6
6 Kerala	14·51	836	845	1,681	58	58	116	19·2
7 Madhya Pradesh	26·80	731	1,191	1,922	28	44	72	11·9
8. Madras	31·38	2,959	3,083	6,042	95	98	193	31·9
9. Mysore	20·58	1,100	1,846	2,946	52	90	143	23·6
10. Orissa	14·94	448	800	1,248	30	54	84	13·9
11. Punjab	16·63	1,118	1,915	3,033	67	115	182	30·1
12 Rajasthan	16·74	213	454	667	13	27	40	6·6
13 Uttar Pradesh	65·60	3,244	2,989	6,233	49	46	95	15·7
14 West Bengal	27·41	6,157	10,434	16,591	225	381	605	100·0
15 Delhi	1·93	771	468	1,239	399	242	642	106·1
16. Himachal Pradesh	1·13	31	42	73	27	37	65	10·7
17 Manipur	0·60	3	21	24	5	35	40	6·6
18. Tripura	0·69	31	145	176	45	210	255	42·1
all India	376·94	28,792	37,810	66,602	76	100	176	29·1

Source Perspective Planning Division, Planning Commission; based on Medical Registers

Table 6E: *Income and expenditure of Universities and colleges in India: 1955-56*

type of institution	recurring expenditure (Rs. lakhs)	source of income (percentage)				type of expenditure (percentage)		
		govt. grants	fees	endowment	others	salary	scholarship	others
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. university teaching	937	49	34	2	15	25	4	71
2. boards of education	132	1	97	—	2	—	—	100
3. professional colleges	700	67	23	3	7	48	14	38
4. general colleges	1,040	34	56	3	7	62	14	24
5. intermediate colleges	125	39	39	7	15	68	22	9
6 total higher	2,934	45	42	3	10	44	10	46
in Rs. lakhs	—	1,320	1,232			1,291	293	

Source · *Education in India,* Vol 1 1955-56.

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Table 7: *Structure of education: selected countries*

level of education	USA 1955	USSR 1957-58	UK 1954	West Germany 1956	France 1954	Japan 1956	China 1955	India 1955-56
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. population (in millions)	165	200	51	51	43	90	608	384
	number of students in thousands (000's)							
2. primary	25,458	25,055	5,484	4,955	4,921	12,956	53,126	22,899
3. secondary	7,961	7,511	2,483	3,668	1,300	8,063	4,473	8,789
4. higher	2,679	2,100	84	127	150	610	292	681
5. total	36,098	34,666	8,051	8,750	6,371	21,629	57,891	32,369
	number of students per 1000 of population							
6. primary	154·3	125·3	107·5	97·2	114·0	144·4	87·4	59·6
7. secondary	48·2	37·6	48·7	71·9	30·2	89·6	7·4	22·9
8. higher	16·2	10·5	1·6	2·5	3·5	6·8	0·5	1·8
9. total	218·7	173·4	157·8	171·6	148·1	240·4	95·3	84·3
	number of secondary and higher students per 1000 primary students							
10. secondary	312·7	299·8	452·8	740·3	264·2	622·3	84·2	383·8
11. higher	105·2	83·8	15·3	25·6	30·5	47·1	5·5	29·7
12. total	417·9	383·6	468·1	765·9	294·7	669·4	89·7	413·5
	number of higher students per 1,000 secondary students							
13. higher	336·5	279·6	33·8	34·6	115·4	75·7	65·3	77·5

Compiled by the Planning Division, Indian Statistical Institute, from

1. Population figures are taken from *UN Statistical Year Book* 1956 and 1957 except for China which is taken from official data (in Chinese)
2. Educational statistics are taken from the following sources:

USA: *Statistical Abstract of USA*, 1956 and 1957.

USSR: *USSR in Figures* (in Russian), 1958. Structural features of Soviet education are not fully revealed in recent data due to the fact that very few children were born during the war.

UK, West Germany, France and Japan: *UN Statistical Year Book, 1957.*

China: From *Report on Fulfilment of the National Economic Plan of the People's Republic of China in 1955.*

India: Basic Statistics relating to Indian Economy (mimeographed: CSO) for primary education; and *Education in India*, Vol 1, 1955-56.

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Table 8: *Enrolment of students by level, subject and sex with percentage 1950-51 and 1956-57*

level and subject	1950-51						1956-57						index 1950-51 =100
	number (000)			percentage			number (000)			percentage			
	boys	girls	total	boys	girls	total	boys	girls	total	boys	girls	total	
(1)	(2.1)	(3.1)	(4.1)	(2 2)	(3.2)	(4 2)	(5 1)	(6 1)	(7 1)	(5.2)	(6 2)	(7.2)	(8)
1. *Intermediate*	198 6	24 4	223 0	89·1	10 9	100·0	381·2	59 5	440·7	86 5	13·5	100·0	198
2. arts	96 3	18 0	114 3	43 2	8 0	51 2	195 1	48 1	243 2	44·3	10 9	55·2	213
3. commerce	16 1	0 1	16 2	7 3	0 0	7 3	35·0	0 2	35 2	7·9	0·1	8·0	217
4. science	84 6	6 3	90 9	37 9	2 9	40 8	145 0	11 2	156 2	32 9	2·5	35·4	172
5. agriculture	1·6	—	1 6	0·7	—	0·7	6 1	—	6 1	1·4	—	1·4	381
6. *Diploma*	9·5	0 3	9 8	97 0	3 0	100 0	26·1	0 7	26 8	97·4	2·6	100·0	273
7. „ engineering and technology	8 2	—	8 2	83 7	—	83·7	23 7	—	23·7	88 4	—	88·4	289
8. „ education	0 4	0 2	0 6	4·1	2 0	6 1	0 7	0 5	1·2	2 6	1·9	4·5	200
9. „ medicine and veterinary	0·9	0 1	1·0	9 2	1·0	10·2	1 7	0 2	1·9	6 4	0 7	7·1	190
10. *Degree*	115 1	13 7	128 8	89 4	10 6	100 0	210 2	34 7	244 9	85 8	14 2	100·0	190
11. arts	44 4	8 9	53 3	34 5	6 9	41·4	88 8	25 0	113 8	36 3	10 2	46 5	214
12. commerce	15·8	0 1	15 9	12 3	—	12 3	31·1	0·2	31·3	12·7	0·1	12·8	197
13. science	29·1	2 4	31 5	22·6	1·9	24·5	48 6	5 8	54 4	19 8	2·4	22 2	173
14. engineering & technology[1]	10 1	—	10·1	7 8	—	7·8	17 7	—	17 7	7·2	—	7 2	175
15. medicine & veterinary[2]	13·0	2 3	15 3	10 1	1 8	11 9	20 3	3·7	24 0	8 3	1 5	9 8	157
16. agriculture	2·7	—	2 7	2 1	—	2·1	3·7	—	3·7	1·5	—	1·5	137
17. *Post-graduate*	34·0	3 9	37 9	89 7	10 3	100 0	56 9	9 3	66 2	86 0	14 0	100 0	175
18. arts	11·0	2·1	13 1	29 0	5·5	34 5	17 3	4·2	21 5	26·1	6·3	32·4	164
19. commerce	2 0	—	2 0	5·3	—	5·3	2 7	—	2 7	4 1	—	4·1	135
20 1. law	13·2	0·3	13 5	34 8	0 8	35·6	18 9	0·4	19·3	28·6	0·6	29·2	143
20.2. law (higher)	0 2	—	0 2	0 5	—	0·5	0 4	—	0 4	0 6	—	0 6	200
21.1. education (B.T.)	2·1	1 0	3 1	5 6	2 6	8 2	7 6	3 3	10 9	11 5	5·0	16·5	352
21.2. education (higher)	0·3	0 1	0 4	0 8	0·3	1·1	0·5	0 3	0 8	0·8	0·4	1 2	200
22. science	4·3	0·4	4 7	11 3	1·1	12 4	7 3	0 9	8·2	11·0	1·4	12·4	174
23.1. technology & engineering[1]	0·2	—	0 2	0 5	—	0 5	0·6	—	0 6	0·9	—	0·9	300
23.2. medicine & veterinary[2]	0 3	—	0 3	0 8	—	0 8	1 0	0 2	1 2	1·5	0 3	1·8	400
24. agriculture *Intermediate*	0·4	—	0·4	1 1	—	1 1	0 6	—	0·6	0·9	—	0 9	150

Table 8: *(contd.)*

25 arts, commerce	112·4	18·1	130·5	50·5	8·0	58·5	230·1	48·3	278·4	52·2	11·0	63·2	213
26. science & technology	86·2	6·3	92·5	38·6	2·9	41·5	151·1	11·2	162·3	34·3	2·5	36·8	175
Degree												100·0	
27. arts, commerce	60·2	9·0	69·2	46·8	6·9	53·7	119·9	25·2	145·1	49·0	10·3	59·3	210
28. science & technology	54·9	4·7	59·6	42·6	3·7	46·3	90·3	9·5	99·8	36·8	3·9	40·7	167
Post-graduate												100·0	
29. arts, law & commerce	26·4	2·4	28·8	69·6	6·3	75·9	39·3	4·6	43·9	59·2	7·1	66·3	152
30. science & technology²	5·2	0·4	5·6	13·7	1·1	14·8	9·5	1·1	10·6	14·3	1·7	16·0	189
31. education	2·4	1·1	3·5	6·4	2·9	9·3	8·1	3·6	11·7	12·3	5·4	17·7	334
32. *All-levels*	357·2	42·3	399·5	89·4	10·6	100·0	674·4	104·2	778·6	86·6	13·4	100·0	195
33. arts, law, commerce	199·0	29·5	228·5	49·8	7·4	57·2	389·9	78·1	468·0	50·1	10·0	60·1	205
34. education³	2·8	1·3	4·1	0·7	0·3	1·0	8·8	4·1	12·9	1·1	0·6	1·7	315
35. science & technology²	155·4	11·5	166·9	38·9	2·9	41·8	275·7	22·0	297·7	35·4	2·8	38·2	178

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[1] Includes agriculture. Includes engineering, medicine and veterinary, agriculture Includes diploma in education.

Source: Perspective Planning Division, Planning Commission.

Table 9: *Out-turn of qualified persons in India by level and subject: 1950-51 and 1955-56*

examination	1950-51				1955-56				index 1950-51 =100
	number passed			percentage of girls	number passed			percentage of girls	
	boys	girls	total		boys	girls	total		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. *Intermediate*	71,272	9,815	81,087	12·1	125,939	20,213	146,152	13·8	180
2. arts	38,748	7,913	46,661	17·0	75,764	16,482	92,246	17·9	198
3. commerce	6,393	17	6,410	0·3	11.216	104	11,320	0·9	177
4. science	25,459	1,884	27,343	6·9	37,716	3,625	41,341	8·8	151
5. agriculture	672	1	673	0·1	1,243	2	1,245	0·2	185
6. *Diploma*	8,724	5,418	14,142	38·3	10,031	2 535	12,566	20·2	89
7. „ engineering & technology	2,026	1	2,027	0·1	4,977	—	4,977	—	246
8. „ others	6,698	5,417	12,115	44·7	5,054	2,535	7,589	33·4	63
9. *Degree*	38,571	5,380	43,951	12·2	60,912	10,648	71,560	14·9	163
10.1. arts (pass)	16.586	3,738	20,324	18·4	29,117	7,899	37,016	21·3	182
10.2. „ (hons)	1,814	450	2,264	19·9	1,865	487	2,352	20·7	104

Table 9: *(contd.)*

11. commerce	5,411	22	5,433	0·4	8,203	50	8,253	0·6	152
12.1. science (pass)	9,640	767	10,407	7·4	13,370	1,577	14,947	10·6	144
12.2. „ (hons.)	713	73	786	9·3	1,077	132	1,209	10·9	154
13. engineering & technology	1,772	1	1,773	0·1	3,810	6	3,816	0·2	215
14. medicine & veterinary	1,598	325	1,923	16·9	2,583	491	3,074	16·0	160
15. agriculture	1,037	4	1,041	0·4	887	6	893	0·7	86
16. *Post-graduate*	12,993	2,052	15,045	13·6	23,527	5,038	28,565	17·6	190
17. arts	5,020	949	5,969	15·9	7,627	1,901	9,528	20·0	160
18. commerce	575	1	576	0·2	1,027	4	1,031	0·4	179
19.1. law	3,474	71	3,545	2·0	5,733	118	5,851	2·0	165
19.2. law (higher)	15	1	16	6·2	41	2	43	4·7	269
20.1. education (B.T.)	2,096	881	2,977	29·6	6,052	2,576	8,628	29·9	290
20.2. education (higher)	151	65	216	30·1	301	142	443	32·1	205
21. science	1,326	72	1,398	5·2	2,277	262	2,539	10·3	182
22.1. engineering	87	1	88	1·1	148	—	148	—	168
22.2. medicine & veterinary	106	11	117	9·4	169	33	202	16·3	173
23. agriculture	143	—	143	—	152	—	152	—	106
Intermediate									
24. arts & commerce	45,141	7,930	53,071	14·9	86,980	16,586	103,566	16·0	195
25. science, agriculture & technology	26,131	1,885	28,016	6·7	38,959	3,627	42,586	8·5	152
Degree									
26. arts, law & commerce	23,811	4,210	28,021	15·0	39,185	8,436	47,621	17·7	170
27. science & technology[1]	14,760	1,170	15,930	7·3	21,727	2,212	23,939	9·2	150
Post-graduate									
28. arts, Law & commerce	9,084	1,022	10,106	10·1	14,428	2,025	16,453	12·3	163
29. science & technology[1]	1,662	84	1,746	4·8	2,746	295	3,041	9·7	174
30. *All-levels*	131,560	22,665	154,225	14·7	220,409	38,434	258,843	14·8	168
31. arts, law & commerce	78,036	13,162	91,198	14·4	140,593	27,047	167,640	16·1	184
32. education	2,247	946	3,193	29·6	6,353	2,718	9,071	30·0	284
33. science & technology[1]	44,579	3,140	47,719	6·6	68,409	6,134	74,543	8·2	156
34. doctorate	115	13	128	10·2	261	24	285	8·4	223

[1] Includes engineering, medicine & veterinary, and agriculture

Source: Perspective Planning Division, Planning Commission

Table 10: *Number of students appearing in and passing different examinations, and the percentage of successful students*

India: 1951-1952 to 1955-1956

	1951-1952	1952-1953	1953-1954	1954-1955	1955-1956
(1)	(2)	(3)	(4)	(5)	(6)
Appeared					
1. Intermediate Arts	109,493	139,422	169,287	189,385	207,118
2. Intermediate Science	61,891	67,155	78,973	85,042	93,405
3. Bachelor of Arts	47,842	54,710	74,824	81,421	79,920
4. Bachelor of Science	23,428	27,457	31,107	34,754	32,667
5. Master of Arts	7,780	7,808	10,281	11,729	13,215
6 Master of Science	2,144	2,114	2,667	2,946	3,142
7. Professional	36,402	41,497	48,237	53,005	48,450
8. total	288,979	340,163	415,376	458,282	477,917
Passed					
9. Matriculation	261,059	334,760	397,005	400,014	429,494
10. Intermediate Arts	52,373	59,703	71,640	86,741	90,182
11. Intermediate Science	25,463	29,318	33,211	39,735	41,557
12. Bachelor of Arts	24,965	27,491	35,773	40,445	37,992
13. Bachelor of Science	11,171	12,526	14,405	16,704	15,997
14. Master of Arts	6,063	6,169	7,753	8,892	9,313
15. Master of Science	1,680	1,694	2,068	2,211	2,456
16. Professional	22,684	26,269	30,162	33,181	35,772
16 1. Commerce	6,785	7,759	8,452	8,773	9,597
16 2. Law	4,538	5,562	6,602	5,996	5,628
16.3. Education & Teacher's Training	5,251	6,215	6,749	9,492	11,106
16.4. Technology & Engineering	2,592	3,117	3,638	3,680	4,444
16.5 Medicine & Veterinary	2,324	2,512	3,541	4,089	3,888
16.6. Agriculture and Forestry	1,194	1,104	1,180	1,151	1,109
17. total	405,458	407,930	592,017	627,923	662,763
Percentage passed					
18. Intermediate Arts	47·8	42·8	42 3	45·8	43 5
19. Intermediate Science	41·1	43·7	42·1	46.7	44·5
20. Bachelor of Arts	52·2	50·2	47·8	49·6	47·5
21. Bachelor of Science	47·7	45·6	46·3	48·1	49·0
22 Master of Arts	77·9	79·0	75 4	75·8	70·5
23 Master of Science	78·4	80·1	77·5	75·1	78·2
24 Intermediate (I A. & I Sc)	45·4	43·1	42·2	46·1	43·8
25 Degree (B A. & B Sc)	50·7	48·4	47·4	49 2	48·0
26. M.A & M Sc.	78 0	79·2	75 8	75·7	72·0
27. Professional	62 3	63·3	62 5	62·6	73·8
28 total	50·0	48·0	46·0	49·7	48·8

[1] Includes "others."

Source: Education in India 1952-1953, 1954-1955 and 1955-1956.

Table 11: *Number and proportion of students in higher courses in relation to number of matriculates in India in 1952*

courses	number on rolls			per cent			number per 10,000 matriculates		
	boys	girls	total	boys	girls	total	boys	girls	total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Intermediate	first year intermediate courses in 1952-53								
(0·1) number of matriculates in 1952	222,371	35,767	258,138	100	100	100	10,000	10,000	10,000
1. total on rolls (1952-53)	153,941	20,330	174,271	69·2	56 8	67·5	6,920	5,680	6,750
2. arts	63,851	13,621	77,472	28·7	38 1	30·0	2,870	3,810	3,000
3. commerce	19,510	127	19,637	8·8	0·4	7·6	880	40	760
4. science	62,548	5,903	68,451	28·2	16·4	26·5	2,820	1,640	2,650
5. agriculture	1,209	—	1,209	0·5	—	0·5	50	—	50
6. diploma: technology	5,667	1	5,668	2·5	—	2·2	250	—	220
7 1. ,, : education	235	201	436	0·1	0·6	0 2	10	60	20
7 2. ,, · others	921	477	1,398	0·4	1 3	0·5	40	130	50
Degree	first year degree courses in 1954-55								
(0.2) number passed intermediate in 1954	98,011	15,612	113,623	100	100	100	4,408	4,365	4,402
8 total on rolls (1954-55)	74,947	10,727	85,674	76·5	68·7	75·4	3,370	2,999	3,319
9. arts (pass & hons.)	33,262	7,654	40,916	33 9	49·1	36·0	1,496	2,140	1,585
10. commerce	12,515	77	12,592	12·8	0·5	11 1	563	22	488
11. science	19,567	2,146	21,713	20·0	13·7	19 4	880	600	841
12 technology & engineering	4,000	1	4,001	4·1	—	3·5	180	—	155
13. medicine & veterinary	3,056	733	3,789	3·1	4·7	3·3	137	205	147
14 agriculture	1,221	5	1,226	1·2	—	1 8	55	1	47
15. diploma (others)	1,326	111	1,437	1·4	0·7	1·3	59	31	56
Post-graduate	first year post-graduate courses in 1956-57								
(0 3) numbers awarded degrees in 1956	51,698	9,332	61,030	100	100	100	2,325	2,609	2,364
16 total on rolls (1956-57)	33,988	6,084	40,072	65 7	65·2	65 7	1,528	1,701	1,552
17. arts	9,015	2,023	11,038	17·4	21·7	18·1	405	566	428
18. commerce	1,422	11	1,433	2 8	0 1	2 3	64	3	55
19. law	11,698	220	11,918	22 6	2·4	19·5	526	61	462
20 education	7,349	3,295	10,644	14 2	35 3	17·5	330	921	412
21. science	3,375	382	3,757	6·5	4·1	6·2	152	107	146
22. agriculture	264	3	267	0 5	—	0·4	12	1	10
23. diploma (others)	865	150	1,015	1·7	1·6	1·7	39	42	39
Science & technology	first year science & technology (totals)								
24. intermediate (1952-53)	69,424	5,904	75,328	31·2	16·4	29·2	3,120	1,640	2,920
25 degree (1954-55)	27,844	2,885	30,729	28·4	18·4	28·0	1,252	806	1,190
26. post-graduate (1956-57)	3,639	385	4,024	7·0	4·1	6·6	164	108	156

Source: Perspective Planning Division, Planning Commission.

Note: Percentage figures given in cols (5), (6) and (7) are on the basis of the number of candidates who passed the appropriate previous examination as given in lines (0.1), (0.2) and (0.3).

Table 12: *Total consumer expenditure per person per 30 days and cumulative percentages of population and consumer expenditure by sub-samples*

National Sample Survey. 9th Round May-November 1955, all-India (rural)[1]

per-centile	number of sample households			total consumer expenditure in Rs per person per 30 days						cumulative percentage of					
				limiting values			average expenditure			total population			total consumer expenditure		
	ss1	ss2	comb	ss1	ss2	comb	ss1	ss2	comb	ss1	ss2	comb	ss1	ss2	comb
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(1)	(12)	(13)	(14)	(15)	(16)
5	39	39	78	4 91	4 79	4 90	4 01	3 82	3 90	6 32	5 58	5 83	1·69	1 39	1 50
10	38	35	71	5·99	5·85	5·92	5·43	5 39	5 39	12·39	10·86	11·56	3 88	3·26	3 54
15	35	37	73	6 74	6·88	6 80	6 39	6 38	6 38	17 17	15 94	16 50	5 91	5·37	5·62
20	36	43	78	7·54	7·90	7 76	7 25	7 35	7 28	22 16	21·47	21·72	8·32	8·03	8·13
25	37	37	76	8 52	8·59	8 56	8·05	8 31	8 20	26 82	27 05	26 98	10 81	11 06	10 97
30	33	42	75	9 36	9·57	9 53	8·96	9·19	9·06	32·78	32·49	32 61	14 36	14·33	14 34
35	38	41	79	10·17	10·39	10·31	9 80	9 95	9 89	37 43	38 06	37 78	17·39	17 95	17·71
40	38	34	72	11·03	11·09	11 07	10 66	10 74	10 69	42 93	43 75	43 13	21 29	21 95	21·48
45	34	36	73	11·80	12·06	11 92	11 42	11 68	11 49	47·56	48 50	47·74	24 80	25 58	24·97
50	41	43	80	12 83	13 02	12 88	12·35	12 59	12 43	53 11	53 41	53 12	29·36	29·62	29·38
55	40	38	78	14 14	14 05	14·14	13·46	13·45	13 44	58 19	58 65	58 37	33 90	34 23	34·03
60	37	43	80	15 13	15 55	15 24	14 57	14 73	14 64	63 77	63 75	63 83	39 30	39 14	39 30
65	42	34	77	16 61	16·97	16 77	15·81	16 12	16 00	68 51	67 87	68 32	44 29	43 48	44 04
70	44	38	82	18·49	18·59	18·56	17 61	17 88	17 78	74 26	72 37	73 38	51 02	48·75	49·97
75	40	39	78	19·85	20·08	20 02	19 14	19 37	19 26	78·60	77 55	77 94	56 55	55·30	55·76
80	37	40	76	22·59	22 01	22 11	21 22	21·27	21 19	82 95	82 65	82·73	62 69	62·40	62 45
85	39	31	72	24 95	23 60	24·35	23 77	22 97	23 36	87 83	86 19	87·07	70 40	67 71	69·12
90	40	40	79	29 57	27·53	28 59	27 40	25 42	26 23	92 60	91 08	91 47	79 09	75 85	76 74
95	40	40	81	38 05	38 38	38 13	32·85	32 06	32 17	96 92	96 07	96 46	88 54	86 29	87 31
100	40	38	78	194 41	128 86	194 41	55 96	53 30	54 31	100	100	100	100	100	100
all	768	768	1536				15·03	15·24	15 15						

Number of sample villages including 4 uninhabited villages in each sub-sample 772 (ss1), 772 (ss2), 1544 (combined).

Number of sample households· 768 (ss1), 768 (ss2) 1536 (combined)

[1] Excludes Jammu & Kashmir

Table 13: *Expenditure in rupees per person per 30 days by items of consumption and by sub-samples*

National Sample Survey 9th Round May-November 1955, All-India (Rural)[1]

percentile	population[2] in lakh (10^5)	expenditure in rupees per person per 30 dvas																				
		food grains			food total			sugar			clothing			education			medicine			medical services		
		s s 1	s s 2	comb	s s 1	s s 2	comb	s s 1	s s 2	comb	s s 1	s s 2	comb	s s 1	s s 2	comb	s s 1	s s 2	comb	s s 1	s s 2	comb
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
5	197	2 34	2 49	2 39	3 12	3 18	3 12	0 04	0 04	0 04	0 10	0 05	0 08	0 00	0 02	0 01	0 01	0 00	0 01	0 00	—	0 00
10	194	3 01	3 14	3 09	4 41	4 22	4 32	0 06	0 06	0 06	0 09	0 23	0 16	—	0 01	0 01	0 06	0 04	0 05	—	—	—
15	167	3 43	3 54	3 48	5 05	4 94	5 02	0 10	0 11	0 11	0 09	0 42	0 22	0 02	0 01	0 02	0 03	0 04	0 04	0 02	0 02	0 02
20	177	3 42	3 88	3 60	5 15	5 63	5 32	0 13	0 11	0 12	0 33	0 59	0 52	0 00	0 01	0 00	0 07	0 01	0 04	0 05	—	0 02
25	178	4 46	4 37	4 50	6 43	6 48	6 47	0 09	0 21	0 14	0 32	0 34	0 31	0 00	0 05	0 03	0 03	0 01	0 02	—	—	—
30	191	4 28	4 50	4 39	6 73	6 86	6 83	0 25	0 16	0 23	0 27	0 61	0 44	0 02	0 01	0 02	0 08	0 03	0 06	0 01	0 06	0 04
35	175	5 11	5 06	5 05	7 43	7 81	7 56	0 28	0 26	0 24	0 72	0 72	0 74	0 03	0 00	0 01	0 03	0 02	0 02	0 04	—	0 02
40	181	5 44	5 43	5 34	8 16	8 11	8 11	0 26	0 25	0 28	0 61	0 66	0 67	0 08	0 02	0 05	0 05	0 01	0 04	—	0 01	—
45	156	5 18	6 02	5 61	8 59	9 00	8 79	0 35	0 28	0 30	0 66	0 63	0 62	0 04	0 02	0 04	0 15	0 23	0 15	0 02	—	0 02
50	182	6 25	5 70	6 00	9 40	9 65	9 52	0 16	0 34	0 28	0 69	0 57	0 62	0 08	0 04	0 06	0 11	0 08	0 12	—	—	0 01
55	177	5 45	6 09	5 80	9 38	9 97	9 70	0 38	0 35	0 34	1 24	0 79	0 99	0 22	0 14	0 17	0 11	0 09	0 10	0 04	0 02	0 03
60	185	7 05	5 99	6 56	11 13	10 22	10 88	0 33	0 44	0 43	1 00	0 97	1 02	0 05	0 21	0 11	0 15	0 33	0 17	0 08	0 00	0 04
65	152	6 29	6 09	6 30	11 01	11 28	11 12	0 64	0 66	0 60	1 85	1 38	1 62	0 04	0 01	0 05	0 21	0 18	0 23	0 08	0 16	0 08
70	171	5 68	7 03	6 18	12 07	12 22	11 98	0 51	0 60	0 53	1 74	1 67	1 69	0 13	0 15	0 13	0 18	0 19	0 24	0 02	0 02	0 06
75	154	7 15	7 23	7 19	13 32	13 44	13 36	0 49	0 66	0 58	2 19	1 88	2 04	0 12	0 07	0 11	0 18	0 32	0 24	0 02	0 05	0 04
80	162	7 41	7 61	7 50	14 22	14 40	14 30	0 87	0 49	0 69	2 12	2 50	2 27	0 21	0 09	0 14	0 18	0 52	0 39	0 08	0 07	0 07
85	147	7 82	8 49	8 05	15 44	16 70	16 25	0 73	0 71	0 76	2 11	0 92	1 50	0 23	0 20	0 22	0 81	0 46	0 49	0 26	0 18	0 14
90	149	8 36	8 09	8 21	16 28	16 52	16 37	0 68	0 98	0 85	3 43	2 53	2 89	0 15	0 29	0 30	0 82	0 44	0 82	0 19	0 19	0 29
95	169	9 66	7 21	8 50	20 13	17 80	18 30	1 14	1 27	1 08	3 86	4 27	4 24	0 71	0 51	0 46	0 43	1 32	0 84	—	0 39	0 21
100	120	10 51	8 97	9 50	22 88	22 65	23 02	0 98	1 24	1 19	5 87	4 90	5 28	0 58	0 29	0 48	8 37	1 12	4 21	3 43	0 42	1 69
all	3384	5 70	5 71	5 70	9 99	10 16	10 08	0 39	0 44	0 41	1 31	1 27	1 29	0 12	0 10	0 11	0 44	0 25	0 34	0 15	0 07	0 11

Number of sample villages including 4 uninhabited villages in each sub-samples 772 (s s 1), 772 (s s 2), 1544 (combined).
Number of sample households 768 (s s 1), 768 (s s 2), 1536 (combined)

[1] Excludes Jammu & Kashmir

[2] Population estimates used elsewhere are based on projection

Table 14: *Cumulative percentages of expenditure per 30 days by items of consumption and by sub-samples*

National Sample Survey: 9th Round: May—November 1955; All-India (Rural)[1]

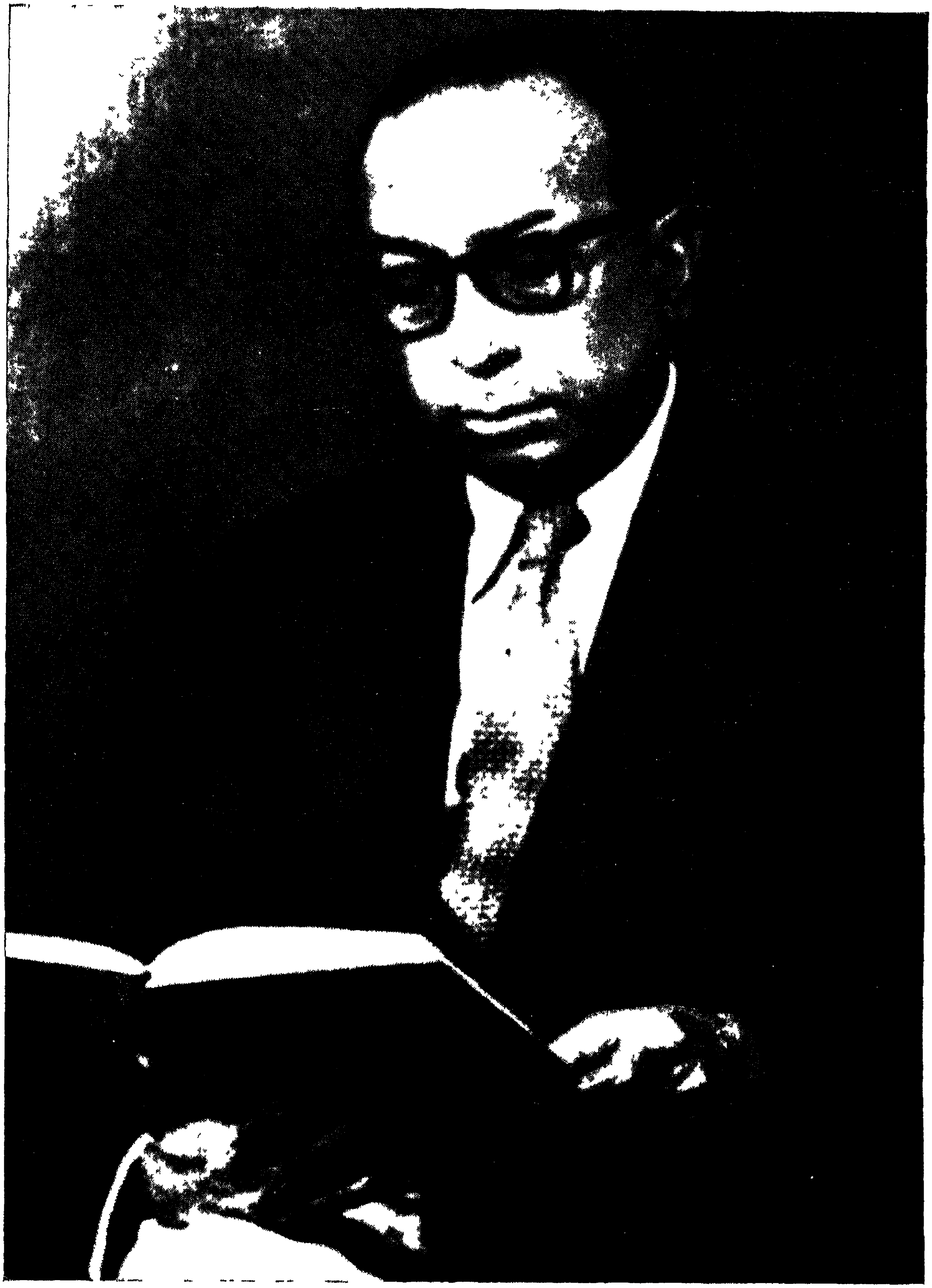
per-centile	cumulative percentage of expenditure on																				
	food grains			food total			sugar			clothing			education			medicine			medical services		
	ss1	ss2	comb	ss1	ss2	comb	ss1	ss2	comb	ss1	ss2	comb	ss1	ss2	comb	ss1	ss2	comb	ss1	ss2	comb
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
5	2 59	2 43	2 44	1 98	1 75	1 80	0 61	0 51	0 52	0 48	0 20	0 34	0 20	0 90	0 52	0 15	0 06	0 12	0 07	—	0 05
10	5 80	5 33	5 54	4 65	3 94	4 26	1 56	1 25	1 34	0 88	1 16	1 04	0 20	1 48	0 79	0 99	0 84	0 94	0 07	—	0 05
15	8 68	8 48	8 55	7 07	6 41	6 72	2 76	2 51	2 62	1 22	2 83	1 88	0 98	1 99	1 45	1 35	1 60	1 45	0 66	1 45	0 92
20	11 67	12 24	11 85	9 64	9 47	9 48	4 39	3 86	4 10	2 47	5 42	4 01	1 14	2 25	1 54	2 12	1 76	2 01	2 38	1 45	2 08
25	15 31	16 51	16 00	12 64	13 03	12 85	5 42	6 57	5 90	3 63	6 93	5 27	1 17	4 87	2 88	2 45	1 91	2 26	2 38	1 45	2 08
30	19 79	20 80	20 34	16 65	16 70	16 67	9 19	8 53	9 06	4 88	9 56	7 18	2 41	5 15	3 78	3 54	2 63	3 22	2 74	6 42	3 94
35	23 96	25 73	24 92	20 12	20 98	20 55	12 46	11 91	12 10	7 43	12 73	10 16	3 47	5 21	4·28	3 83	3 04	3 55	3 91	6 42	4 73
40	29 22	31 15	29 92	24 60	25 52	24 85	16 14	15 22	15 66	9 98	15 71	12 94	7 14	6 21	6 71	4 46	3 26	4 09	3 91	6 78	4 74
45	33 42	36 16	34 45	28 58	29 74	28 87	20 25	18 28	19 00	12 31	18 07	15 15	8 87	7 18	8 24	6 05	7 60	6 16	4 65	6 78	5 35
50	39 51	41 07	40 12	33 80	34 39	33 96	22 58	22 15	22 60	15 24	20 28	17 75	12 33	9 29	11 12	7 39	9 12	8 04	4 65	6 78	5 64
55	44 36	46 66	45 45	38 57	39 54	39 01	27 51	26 34	26 86	20 04	23 55	21 79	21 76	16 60	19 39	8 70	10 99	9 57	6 09	8 43	6 86
60	51 26	51 01	52 73	44 78	44 66	44 91	32 24	31 52	32 58	24 29	27 48	26 12	23 96	27 43	24 70	10 62	17 66	12 33	8 89	8 60	8 81
65	56 50	56 40	56 69	50 02	49 24	49 86	39 98	37 80	39 13	31 02	31 97	31 79	25 57	27 71	26 60	13 35	20 65	15 35	11 44	18 13	11 87
70	62 22	61 96	62 17	56 95	54 66	55 88	47 42	44 03	45 59	38 66	37 92	38 44	31 93	34 37	32 49	15 66	24 14	18 94	12 03	19 51	14 48
75	67 67	68 51	67 92	62 75	61 51	61 92	52 81	51 87	51 96	45 93	45 58	45 65	36 46	37 94	37 12	17 49	30 63	22 07	12 63	23 10	16 05
80	73 32	75 32	74 22	68 93	68 73	68 73	62 44	57 59	59 95	52 99	55 67	54 10	44 18	42 45	43 21	19 30	41 28	27 50	14 98	27 90	19 19
85	80 01	80 58	80 33	76 47	74 55	75 71	71 51	63 33	67 86	60 87	58 25	59 15	53 56	49 65	51 72	28 26	47 83	33 70	23 55	36 93	24 71
90	87 00	87 52	86 66	84 24	82 50	82 86	79 77	74 33	76 85	73 39	68 02	69 03	59 38	63 59	63 90	37 17	56 32	44 24	29 72	49 81	36 23
95	94·32	93 82	94 09	92 95	91 23	91 91	92 32	88 84	89 81	86 15	84 79	85 45	85 04	88 75	84 73	41 38	82 47	56 49	29 72	76 93	45 66
100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Number of sample villages including 4 uninhabited villages in each sub-sample 772 (ss1), 772 (ss2), 1544 (combined)
Number of sample households 768 (ss1), 768 (ss2), 1536 (combined).

[1] Excludes Jammu & Kashmir.

Professor Sisir Kumar Mitra, FNA*

(Foundation Fellow; President, 1959—60)



Professor S K Mitra was born in Calcutta on October 24, 1890. He received the DSc degree from University of Calcutta in 1919 and University of Sorbonne (France) in 1923. He was the Professor of Physics, University of Calcutta; Head, Institute of Radio Physics and Electronics; the Administrator of the Board of Secondary Education, West Bengal and the National Research Professor in Physics (1962). Professor Mitra was a Fellow, the Royal Society, London (1958); Chairman, Radio Research Committee (1942-48); President, Asiatic Society of Bengal (1951-52) and General President, Indian Science Congress (1955). He was the recipient of J K Mukherjee Gold Medal of Indian Association for the Cultivation of Science (1943), Science Congress (Calcutta) Medal of the Asiatic Society (1956); Sir Devaprasad Sarbadhikari Gold Medal of Calcutta University (1961) and the Presidential Award, Padma Bhushan in 1962. Professor Mitra introduced Radio Research in the country. The transmitter installed in his wireless laboratory (call sign, CZ) at University College of Science was one of the only two transmitters broadcasting regular programmes in eastern region of India before 1927. His research work on the physics of ionosphere not only gave general picture of the ionospheric conditions in a sub-tropical region of low altitute like Calcutta, but the results threw considerable light on the effect of thunderstorms, magnetic storms and meteoric showers on upper atmospheric ionization. His first successful explanation of the formation of E layer at a height of 100 km by solar ultraviolet radiation received wide acclaim. His research work on the Upper Atmosphere ionization and his ambitious treatise on 'The Upper Atmosphere', brought him international recognition. He is also known for his theory of Active Nitrogen.

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*died August 13, 1963.

UPPER ATMOSPHERE AND SPACE EXPLORATION WITH ARTIFICIAL SATELLITES

S K Mitra

(delivered at Bombay on January 1960)

I propose in my address to give a brief account of the progress that has been made in our knowledge of the high regions of the atmosphere and of the space beyond—hundreds and thousands of kilometres above the surface of the earth—with the help of artificial satellites. I have chosen this subject, because for many years the upper atmosphere has been my particular field of study, and it has been the general practice for the President of the Institute to speak at the Anniversary meeting on a subject in which he is specially interested

The launching of the artificial satellites had, perhaps, been the most spectacular item of the programme of the International Geophysical Year (1st July, 1957 to 31st December, 1958). The first satellite Sputnik I was put into orbit round the earth by the Russians on October 4, 1957; the latest, Discoverer VIII, has been launched by the Americans on November 20, 1959 In between, there have been 12 other satellite launchings Of these five have crashed back to earth and nine (together with the launching rockets of some) are still in their orbits (*see* Table I). Besides, there had been near-successful or successful launchings of lunar rockets. Of these two missed the moon and have become instead man-made planets of the sun, two had reached about one-third the distance to the moon, one has hit the moon and one has orbited round it taking photographs of its unobserved face.

To many, the actual launching, putting a terrestrial object into an orbit round the earth as a satellite, had been an end in itself satisfying the adventurous spirit of man. To them further launchings since that of Sputnik I are of little interest. To others, successful overcoming of gravity has been of special appeal as this is the first step towards manned flight into space. To the man of science, however, the satellite programme is of the profoundest interest for other reasons. Man's vision of the sky had hitherto been restricted by the screening effect of the atmosphere. He could use only two narrow windows in the wide range of electromagnetic waves, one corresponding to light and another to radio. Now with an instrumented satellite stationed above the dense atmosphere he is having a 'greatly increased view of the denizens of heavens.' The satellite programme is also supplying for the first time reliable data of the physical conditions of the hitherto inaccessible remote regions of the atmosphere and outer space, is helping in gaining new knowledge in the field of atomic physics and will undoubtedly benefit two important applied sciences, Radio Communication and Meteorology. Further, in no distant future, it will provide firm answer to the question: Is there life in any of the planets? And, finally as has been proved again and again in the field of pure researches, the satellite programme may yield, in the long run, unexpected practical dividends.

The success of the satellite programme of upper atmosphere and space exploration has been due to successful developments in instrumentation and remote control techniques, as witnessed by the photography and transmission of the photograph line by line by the instruments of Lunik III. The nose-cone of the satellite (or the rocket) is, in fact, a space laboratory. It is amazing how the variety of instruments and apparatus, all working

Table I: *Earth-satellites in orbit*

Designation	Launching date and life	Weight (kg)	Perigee height (km)	Apogee height (km)
Explorer I	1 February, 1958 4 years	14·0	304 21 March, 1959	1,937
Vanguard I	17 March, 1958 100 years (?)	1·5	568 12 March, 1959	3,428
Sputnik III	15 May, 1958 19 months	1,346·4	190 2 March, 1959	1,214
Explorer IV	26 July, 1958 13 months (?)	17·5	222 21 March, 1959	1,296
Vanguard II	17 February, 1959 50 years	9·8	485	2,282
Explorer VI	7 August, 1959	64·5	225	37,000
Explorer VII	13 October, 1959	41·6		
Discoverer VII	7 November, 1959			
Discoverer VIII	20 November, 1959			

Note:—The list excludes the carrier rockets of some of the satellites which are still in orbit and are also to be regarded as earth-satellites.

Table II: *Moon rockets*

Designation	Launching date	Remarks
Pioneer I	11 October, 1958	Reached 114,100 km.
Pioneer III	6 December, 1958	Reached 108,700 km Transmitted during flight radiation belt data.
Lunik I	2 January, 1959	Passed the moon at 6,400 km. distance; is an artificial planet of the sun.
Pioneer IV	3 March, 1959	Artificial planet of the sun
Lunik II	13 September, 1959	Hit the moon. Transmitted during flight magnetic field, cosmic rays, micrometeorite and interplanetary gas data.
Lunik III	3 October, 1959	Passed round the moon taking photograph of its far side and transmitting the same to earth.

automatically and subject to vibrations, accelerations, heating and extremes of low pressure have been 'miniaturized' within the strict limits of weight and space available. A list of some of the instruments and apparatus, as ordinarily carried, is as follows: Temperature and pressure gauges, magnetometer for measuring the intensity of the terrestrial magnetic field, Geiger counters for cosmic rays, instruments for registering photons in the same, photo-multipliers for solar corpuscular radiation, ion traps for ionization measurements, devices to register micrometeors, mass spectrometer for determining the nature of atmospheric ions, and time programming and temperature regulating devices. The satellites also carry radio transmitters with telemetering systems for sending the data racorded by the instruments to the ground observing stations. The signals from the transmitters also enable the stations to keep track of the satellite. A major problem has been that of the batteries, sufficiently light and compact, which would supply power for a long time to the transmitters and to the various recording instruments. This has largely been solved by the development of special type of solar cells which are continually charged by solar energy. It has also been reported that small lightweight atomic reactor, weighing no more than 220 lb, fuelled with enriched uranium may soon be available for providing power to the satellite instruments and transmitters.

Density and Temperature Distribution in the Upper Atmosphere

Density distribution is generally computed from the orbital data of the satellite. The orbit of the satellite, even in its very early days, is not fixed (relatively to the earth) but changes continually. This is due firstly to the atmospheric drag effect (specially at its perigee when it passes through the comparatively dense atmosphere) and secondly to the irregular gravitational pull of the earth, the nature of which differs significantly from the ideal central pull of a spherical earth. Fortunately, the two effects can be separated Hence, it is possible, on the one hand, to estimate the density of the atmosphere in the region of the drag, and, on the other, to determine accurately the distribution of the gravitational field of the earth. The results, as deduced by the processing of the drag effect from the satellite tracking data, all show that the density of the atmosphere in the highest regions studied—two hundred kilometres and above—is more than one order higher than that of the various model atmospheres proposed from time to time. Further, close analysis of the secular variation of the drag shows that the variations are not smooth as they ought to be if the atmospheric density distribution remained constant in time They are sometimes irregular and the irregularities are related to the occurrence of solar disturbances. The most conspicuous of the irregularities is the sudden increase in the drag effect associated with solar flares (Jacchia, 1959). The interesting thing about the increase is that it occurs not at the time of the flare, but about 24 hours later. This shows that the drag increase is caused by increased density due to heating by absorption of solar corpuscular emissions which take about the same time to reach the earth. Besides association with flares, association between smaller irregularities in the drag effect and the variations in intensity of magnetic disturbances (geomagnetic planetary indices *Kp*) has also been reported (Jacchia, 1959). There is close resemblance between the two variation curves even in details. And, since the geomagnetic disturbance is known to be associated with solar corpuscular emission, this again shows that the upper atmosphere density is affected by heating due to absorption of such emissions. Finally, the drag effect variations also generally confirm the results obtained with high altitude rockets regarding diurnal, seasonal and latitudinal variations of the upper atmosphere density (Groves, 1958; King-Hele and Walker, 1959).

It may be noted that the result of high density in the highest atmospheric regions referred to above is not quite unexpected. It confirms the assumption of a rising temperature in these regions as has always been made in constructing atmospheric models. In Table IV are given the densities and temperatures at some selected heights of such a model constructed some years ago on certain assumptions (Mitra, 1952). These may be compared with the corresponding figures in the model shown in Table III proposed recently by A P Mitra and S B Mathur (1959) from high altitude rocket and satellite data. In both the models there is significant density even at 800 km height. It will presently be seen that

Table III: *A model upper atmosphere based on high altitude rocket and satellite data*

Height (km)	Density (gm/cm^3)	Pressure (mm of Hg)	Temperature (°K)
800	$6\cdot00\times10^{-17}$	$4\cdot81\times10^{-10}$	2068
500	$1\cdot54\times10^{-15}$	$9\cdot46\times10^{-9}$	1591
300	$4\cdot97\times10^{-14}$	$1\cdot85\times10^{-7}$	1023
130	$2\cdot74\times10^{-11}$	$3\cdot46\times10^{-5}$	462

Table IV: *An older model*

Height (km)	Density (gm/cm^3)	Pressure (mm. of Hg)	Temperature (°K)
800	$3\cdot67\times10^{-17}$	$2\cdot13\times10^{-10}$	3040
500	$7\cdot00\times10^{-16}$	$2\cdot25\times10^{-8}$	1840
300	$2\cdot11\times10^{-14}$	$3\cdot83\times10^{-8}$	1040
110	$4\cdot98\times10^{-10}$	$2\cdot70\times10^{-4}$	270
100	$1\cdot74\times10^{-9}$	$1\cdot00\times10^{-3}$	240

ionospheric studies with satellites and by other methods indicate that the atmosphere extends to much greater heights and merges with the interstellar gas at a distance of several tens of earth-radii.

Ionosphere

The ionosphere produces a number of effects on the radio signals transmitted through it from a fast-moving satellite Careful measurements of these effects, combined with the positional data of the satellite, enable one to estimate the electron concentration in the ionosphere at great heights. These measurements are of considerable importance, because ionospheric observations as carried out with the transmitter located on the ground cannot give any information of electron concentration in regions above the level of maximum ionization of the $F2$ layer, that is, above about 300 km Measurements as made till now with satellite signals all show that the electron concentration above this height decreases much more slowly than hitherto supposed. For the region between 300 km and 500 km the satellite results confirm the earlier results obtained with high flying rockets. The ionospheric effects on satellite radio signals as have been recorded and analysed are: Faraday fading effect, Doppler effect and refraction effects.

Faraday fading effect: The ionosphere, so far as the propagation of radio waves is concerned, acts as a doubly refracting medium due to the influence of the earth's magnetic field. At any level there are two characteristic waves (magneto-ionic splitting) generally elliptically polarized. The plane of polarization of a plane polarized wave is rotated as it travels through the ionosphere, and the amount of rotation, as observed at the receiving station, alters as the satellite changes its position (Faraday rotation). There is thus fading of the signal on a linearly polarized aerial, its rate depending on the rate of change of the difference in phase between the two characteristic waves (Faraday fading). Since this latter rate depends on the electron content of the path in the length between the satellite and the receiving station, it is possible to compute the amount from an analysis of the records of Faraday fading (Berning, 1959) Estimates have been made by this method by observation of Sputnik I signals (Aitchison, Thomson and Weekes, 1959). The results show that at night the ionization density above the maximum of the $F2$ region decreases slowly and that at 100 km height above the same it did not decrease by more than 20 per cent

Doppler effect: There is Doppler shift in frequency of the transmitted signal due to the motion of the satellite (Berning, 1959). The amount of the shift is determined by the rate of change of phase path of the radio ray caused by the motion. The phase path depends on the refractive index of the medium, that is, on the electron distribution in the path As the satellite moves over the observing range of the station, the slant of the phase path changes and there is time variation of the Doppler frequency shift If the satellite transmits on two different frequencies, then the time variation curves of the two, which in the absence of the ionosphere would have been the same, are different, though they may be parallel and lie close to one another. The ionosphere effect on Doppler shift, and hence ionosphere electron content, can be deduced with convenience from the observed frequency shifts of two signal frequencies, one double that of the other, and the satellite positional data (Thomas and Hibberd, 1959). If the Doppler shift frequency for the lower one be denoted by D (1) and that for the double frequency by D (2) then the difference 2D (1) —D (2) for two different positions of the satellite is associated with the electron content of the phase path between the two positions Accurate data of the Doppler shifts, as also those of the satellite positions and the directions of reception of the transmitted signals, are needed for ionospheric computation by this method. It has been shown that results may be obtained more eadily if the Doppler shift data are used n conjunction with the Faraday fading lata (Thomas and Hibberd, 1959). The wo curves are plots of Doppler shift variation with time for the two frequenies 20 Mc/sec and 40 Mc/sec transmitted rom Sputnik I. They were taken in England at the Post Office Radio Stations t Baldock and Banbury. The area PQR epresents the total number of cycles of Doppler shift frequency for the 40 Mc/sec wave when the satellite moves from one position to a contiguous one in the time nterval between the two ordinates, and he area XYZ represents twice that for he 20 Mc/sec wave The difference of he two areas is proportional to the effect of the ionosphere

Refraction effect— Transmission Cone. The path of radio waves entering an ionospheric ayer is bent by refraction The refractive ndex being less than unity the bending s away from the normal (Berning, 1959). Further, the waves can enter only when he frequency is greater than the critical requency (penetration frequency for vertial incidence) of the densest top layer $F2$ layer) and is also incident at an ngle less than the corresponding critical angle of incidence Due to the bending of the path, the apparent position of the atellite, as indicated by the direction of arrival of the waves, is different from its rue position. If the frequency of the waves is not far removed from the critical requency (e.g. 20 Mc/sec of Sputnik I), he obliquely incident waves may be bent upward by 'total reflection' effect and not penetrate into the ionosphere. In uch case a 'transmission cone' is produced above the level of maximum electron density. Signals from the satellite can only be received when the atellite is within the cone. By observing he times of appearance and disappearance within and beyond respectively of his transmission cone, the nature of lectron density distribution above the $F2$ layer may be deduced. For example, f the path of the satellite above the observing station is not horizontal and its height changes appreciably, then the time of its appearance within the cone will not be symmetrical with that of its disappearance beyond the same Analysis of such asymmetry enables one to measure the slope of the cone at the satellite orbit and hence also estimate the electron density at these heights.

Refraction effect—'Radio Rising' and 'Radio Setting' of Satellite: The times of rising and setting of a satellite as observed visually (may be through a telescope) are not the same as those 'observed' by the first detection and the disappearance respectively of its radio signals The 'radio rise' occurs earlier and the 'radio setting' occurs later than the optical rising and setting respectively. Now, as the refraction effect depends upon the electron concentration and its variation in the path of travel of the signal, these quantities, for the high regions of pass of the satellite, can be computed from records of the times of optical rising or setting, the satellite positions and knowledge of the ionosphere in the lower region (Al'pert, 1958) In Table V is given a set of results obtained by the above method from radio rising and setting data of Sputnik I The values of electron concentration up to the altitude of 600 km were obtained directly from experimental data, those beyond are extrapolated It is to be noted that the values up to 500 km are in good agreement with those obtained from rocket exploration. The values at greater heights are, however, underestimates, by more than one order, as compared with the values determined from moon Radio-echoes and 'Whistler' data (*vide infra*).

The figures in the last column—density of neutral particles at great heights—are obtained from a consideration of the lifetime $T(e)$ in these regions of a free electron. This time is reckoned by the time that elapses between the production of the electron by ionization and its disappearance by recombination. The time is of the order 10^5-10^6 seconds or more, that is, over 24 hours. If the time between individual ionizations be $T(n)$, then $T(n)/T(e)$ is of the same order as the ratio between the number density of the neutral particles and that of the electrons. As $T(n)$ and $T(e)$ can be estimated without difficulty, the data of the number density of the electrons allow one to estimate also the number density of the neutral particles at the corresponding heights. The number density of 10^7 at 600 km in the table below may be compared with the value 10^6 at 800 km level as deduced from Table IV

Table V: *Height distribution of electrons deduced from 'radio rising' and 'radio setting' of satellite. Neutral particle density is computed*

Altitude (km)	Electron concentration (N per cm^3)	Density of neutral particles (N per cm^3)
200	1×10^5	. ...
320	1.8×10^6	.
400	1.4×10^6	6×10^8
600	7×10^5	1×10^7
1,150	1×10^5	2×10^5
1,800	1×10^4	2×10^3
2,450	1×10^3	20
3,100	1×10^2	<1

Van Allen Corpuscular Radiation Belts

Discovery and structure: A major achievement of the satellite programme of the IGY (to which also contributed the so-called moon-probes) is the discovery of the existence round the earth of extensive regions or 'belts' of intense corpuscular radiations extending to several earth-radii (Van Allen and Frank, 1959; Van Allen, Mc Ilwain and Ludwig, 1959) The belts were discovered independently by the American and the Russian scientists; but most of the systematic study is due to the American group led by J A Van Allen of the State University of Iowa, USA. The patterns of the intensity variation of the corpuscular radiations—contours of equal intensity—follow the configuration of the magnetic lines of force of the earth. Hence it is inferred that the corpuscles are charged particles; because, magnetic field has no effect on neutral particles. The corpuscles are distributed within doughnut shaped belts round the earth centred on its magnetic equator There are two zones of high intensity with a gap of low intensity between them. The inner zone is situated at a mean distance of 13,000 km and the outer at about 25,000 km from the centre of the earth. The cross-sections of the belts are roughly of crescent shape. The high latitude ends of the 'horns' are close to the low latitude edge of the zones of the most frequent occurrence of aurora round the north and south magnetic poles.

The corpuscles in the inner belt have a soft and a hard components The energy of the soft ones is round 100,000 eV and of the hard ranges from 6 million eV up. The low-energy particles are believed to be electrons and the high energy ones to be protons of energy 100 million volts. Little is known about the nature or the energy of outer belt particles, only there is some evidence of the presence of particles in the energy range 650,000 eV.

Trapped particles—Theoretical Considerations: Theoretical considerations, as also results of experiments carried out in laboratory and in the upper atmosphere, show that the charged particles, by virtue of their momentum, may be trapped by the magnetic field of the earth The theoretical considerations are more than half a century old and are due to two very distinguished Norwegian physicists, K Birkeland and Carl Stormer (*see* Mitra, 1952). These authors, specially the latter, studied in great detail the motion of a charged particle in the field of a dipole magnet to which the configuration of the magnetic field of the earth closely approximates They showed that there exist, round the dipole, spaces 'allowed' and 'forbidden' to the charged particles. Particles trapped inside the allowed space can leave only by way of the 'horns' where they contact the earth. The radiation belts discovered are evidently the Birkeland-Störmer allowed spaces in the magnetic field of the earth, and the particles found inside the belts must have gained access across the forbidden regions by some special process to be investigated.

The motions of the particles in the trapping belts are not at random as those of thermally agitated particles but follow definite patterns controlled by the magnetic field of the earth. The dominant characteristic of the motion is a circular component about the lines of force. Besides the circular component, the particles have three other component motions. (*a*) a north-south, back and forth, travel in latitude along helical paths guided by the curved lines of force, (*b*) a drift in longitude east or west (according to the charge of the particle), and (*c*) a drift and diffusion in height. The north-south motions are due to velocity components that the particles may possess along the lines of force, the oscillations being caused by a sort of reflection effect at points where the lines of force become crowded. The east or west drift is attributed to the magnetic field strength varying not only north-south but also in height. The drift in height is caused by the presence of inhomogeneities of the magnetic field, that is, it occurs when and where the field configuration is significantly different from that of an ideal dipole. In such case there is variation of field intensity with change of longitude (which is absent in the case of the ideal dipole) and this gives rise to the drift.

To obtain some idea of the magnitudes involved we note (Gold, 1959): A proton of 10 million eV energy, at a height of 3,000 km above the equator, will have approximately a circling radius of 3 km. The time period of the north-south oscillations, depending upon the energy, ranges from a fraction of a second to a few seconds. The time for drifting once round the earth, east or west, depends on the energy and height of the particles and is within a few minutes to a few hours. The time for drifts in height is difficult to estimate, but it must be much greater than those of the other two components and is to be reckoned in tens of hours or days.

Laboratory and high altitude experiments—Project Argus: To demonstrate the existence of 'allowed' and 'forbidden' spaces Birkeland carried out experiments as early as 1896. He constructed a large vacuum chamber and placed in its centre a magnetized iron sphere representing the earth which he called 'Terrella' The sphere was exposed to cathode rays produced in the chamber. Under appropriate conditions a dark toroidal region was formed surrounding the sphere. This was the forbidden space. The space allowed to the cathode rays, with the 'horns' contacting the sphere, is also seen in the figure (Birkeland, 1896).

The laboratory experiments of Birkeland were simulated on a grand global scale 62 years later by the American Navy by nuclear firings at high altitudes (Anon, 1959*a*). The idea was to produce by the firings energetic electrons in the rarefied upper atmosphere and to test if, as predicted by theory, the electrons would remain trapped by the earth's magnetic field for any considerable length of time. The electrons would have remained indefinitely, if the allowed space were a perfect vacuum Actually the particles would lose energy by collision and escape, or disappear by recombination The lifetime under such condition is estimated to range from a few seconds for altitudes of a few hundred kilometres to years for some thousands of kilometres

The nuclear firings (Project Argus) were done at an altitude of 300 miles from the missile ship Norton Sound on the 27th and 30th of August and the 6th of September, 1958. The site chosen was in the Southern Hemisphere over the Atlantic Ocean, near the Falkland Islands, approximately 45°S between the Greenwich Meridian and 30°W. The high energy electrons produced by the explosion, instead of dispersing all round, were trapped by the arching lines of force passing through the site of the explosion. They travelled north and south spiralling about the lines of force, those going south entered into the dense atmosphere not far from the missile ship and caused artificial auroral glow; those that went north, climbing along the lines of force, came down and re-entered the dense atmosphere near the Azore Islands in the Northern Hemisphere producing bright auroral glow there also. The electrons also drifted across the lines of force spreading round the globe within a doughnut shaped shell, in about an hour's time. How long they remained within the shell is not exactly known, though traces of the shell persisted for many days, even weeks. The monitoring of the effects of the explosion was done by the American earth-satellite Explorer IV put into orbit on July 26, 1958, and by a number of high altitude rockets specially launched for the purpose.

Two other atomic charges were also fired by the USA in the Northern Hemisphere over Johnston Island, south-west of Hawaii, in the Pacific Ocean at a much lower altitude, 100 miles. The artificial aurora produced in the south across the magnetic equator was observed from the Samoa Islands. As the electrons in this low altitude explosion were produced in a region of insufficient vacuum, they were quickly lost by collisions and the spread round the globe was negligible.

Origin of the belts: The problems of the Van Allen belts are: What is the source of the particles? Are they of solar, terrestrial or cosmic origin? How do the particles, charged as they are, find their way into the trapping zones across the 'forbidden space'? Further, why do not the two zones of high intensity merge into one another by diffusion?

It is now the general opinion that the source of the particles in the outer belt is streams of charged particles emitted from the sun and that of the inner one is probably cosmic ray neutrons produced in the atmosphere The arguments in favour of these hypotheses may briefly be noted.

Regarding the outer belt there is strong observational evidence of its solar origin. The radiation intensity in the outer belt was found to be greatly increased during solar disturbances. The evidence was supplied by observations from the American lunar rockets Pioneer III and Pioneer IV. Pioneer III flight was during a quiet period of the sun and Pioneer IV 'had followed directly on 5 days of continuous and unusually intense solar activity'. It was found that radiation intensity during Poineer IV flight was several times that during the Pioneer III flight It is, therefore, evident that particles of solar origin must have got into the belt. The mechanism of the ingress of the particles is, however, ill understood. But it is fairly certain that it is associated with the inhomogeneities produced in the earth's magnetic field by the approach of the stream of solar particles (Gold, 1959; Anon, 1959*a*). The solar streams are known to carry with them magnetic field and they also cause magnetic storms. The interaction of this field with earth's field perturbs the latter and allows the solar particles to drift across the 'forbidden space' and enter the trapping zones. The time period of the drift is difficult to estimate, but it must be much greater than those of the two other regular motions and is to be reckoned in days. It is to be noted that the sun is now known to emit particles over a very wide range of energy spectrum—from billions of eV cosmic rays to only a few electron volts. It is very likely that the sun emits particles in the energy ranges as observed in the belts not only during disturbed periods, but continuously.

The solar origin hypothesis of the outer radiation belt explains a long standing difficulty of the auroras. The solar corpuscles, if they are to reach the auroral latitudes (within 25° from the magnetic poles), must possess sufficient momentum to overcome the lateral push of the magnetic lines of force. Simple calculations show that for electron or for proton the speed required is too great. Their penetrating power would be so high that they will not be able to ionize the atmosphere at the height of the most frequent occurrence of aurora (round 100 km). The hypothesis meets this difficulty, since the particles of requisite energy are not required to reach the auroral belts directly, but *via* the trapping regions. The particles enter the regions by slow drift motion in height and hence the delay of about a day between the occurrence of a solar outburst accompanied by emission of energetic particles and that of the corresponding auroral display is explained.

It is also to be mentioned in this connection that there are permanent inhomogeneities in the earth's field There are extensive regions on the earth where the field differs from that of the best fitting dipole by more than 20 per cent. The inhomogeneities resulting from such irregularity being due to internal cause decrease rapidly with height. Nevertheless, they may allow particles to escape from the trapped regions. Loss by this mode of motion has, in fact, been invoked to explain the gap of depleted population between the two high intensity zones (Dessler, 1959) It has been pointed out that the lines of force which touch the region of extensive magnetic irregularity over South Africa pass through this gap between the two belts.

In the neutron hypothesis of the inner belt it is assumed that the particles have their origin in the neutrons produced by interaction of cosmic rays with atmospheric particles (Kellog, 1959; Singer, 1958; Vernov, 1959). The neutrons are produced round 30 km altitude and the upward moving ones escape from the dense atmosphere and, being unaffected by the magnetic field (as they are unchanged), find their way into the 'forbidden' belts. The mean life of a neutron at rest is 12 minutes and it is found that the velocity of the slow ones is such that they would decay within the belts producing fast electrons and protons. Though the rate of injection of electrons by this mode is very slow, yet, as the lifetime of particles in the belts is very long, there is ample time for the building up of a substantial population of particles. However, calculations show that the total energy that could be provided by this process falls short of that required due to loss by auroral displays by a factor of 10,000 The neutron hypothesis cannot, therefore, explain the outer belt which is closely related to the auroral phenomena

Ring current in outer space: A remarkable announcement made recently by the Russians seems to support the natural and tempting assumption that the radiation belts may be the seat of a ring current round the earth (Anon, 1959*b*). The possibility of such a ring current, produced by deviation of charged solar corpuscles, had been suggested by Stormer and also figures in the theories of magnetic storms proposed from time to time. Measurements of the magnetic field intensity in outer space by magnetometer carried in Lunik I show that there is a drop in the intensity of the field between 15,000 km and 30,000 km from the centre of the earth The maximum of the drop occurs in the region of the outer Van Allen belt It is assumed that the Lunik passed through an electric current system at this distance, between 20,000 and 21,000 km which is not far from the central portion of the outer Van Allen belt.

Radiation hazard: A question of vital importance in manned flights is radiation hazard Are the corpuscular radiations in space intense enough to be injurious to the occupants of a space vehicle? The biological effects of radiation are due to the ionization it produces. The capacity for ionization is measured in roentgens, one roentgen being the quantity of radiation (X or gamma radiation) that would produce ions carrying one electrostatic unit quantity of electricity of either sign in one cm^3 of dry air at NTP. The exposure levels in the belts, as computed from the counting rates of the particles, depend upon the assumption made regarding the nature of the particles (Van Allen and Frank, 1959). It has been found that, if the particles were electrons only, the maximum observed exposure level in the hearts of the two zones was in the range 5-10 roentgens/hr. If, on the other hand, the particles are protons the level is 50-100 roentgens/hr. These are near lethal doses, recalling that the maximum permissible amount thought safe for man is 100 roentgens every three hours received in his whole life.

Cosmic Ray Observations

Cosmic ray observations with satellite borne instruments have given useful information about the total flux of the rays at hitherto inaccessible heights, on the variation of its intensity with latitude, and on intensity variation with time. The last named one is of special importance, because it is the low-energy particles that are most subject to variations and these are precisely the particles that do not reach the vicinity of the earth due to atmospheric absorption. Study of these variations is of considerable interest because it gives information about the origin of the particles, about the solar emission of such particles and also helps to understand the nature of magnetic storms known to be associated with such emissions.

The first cosmic ray studies were those made with data radio-telemetered from Sputnik II. The satellite carried, amongst other instruments, two identical charged particle counters (the shielding matter round the counters was 10 gm/cm^2 in the mean), the readings of one serving to check those of the other. The informations obtained were as follows (Vernov, Grigorov, Logachev and Chudakov, 1958).

The latitude and longitude dependence of the cosmic rays showed that the lines of equal intensity do not follow the geomagnetic parallels as expected from theory. This confirms the view that the cosmic ray equator does not coincide with the geomagnetic equator.

Above 200 km the intensity of the rays increased with height. At 700 km it was about 40 per cent more than that at 200 km. The increase with height is ascribed principally to two causes: First, decrease of intensity of the earth's magnetic field with height; this allows particles of lower energy to reach the high levels. Secondly, due to the reduction of the screening effect of the earth, more particles (isotropically distributed) reach the instruments mounted in the satellite.

On one of the days of observations (November 7, 1957, 0436 hr to 0449 hr. Moscow time) sudden fluctuations of intensity were recorded over latitude 58°-65°N. Occasionally the increase in intensity amounted to more than 50 per cent of the mean intensity These fluctuations and increase of intensity occurred at a time when cosmic ray recording instruments on the earth's surface did not detect any noticeable variation. The phenomenon may be ascribed to sudden emission of low-energy particles from the sun particles which were abosorbed by the terrestrial atmosphere.

The American lunar rocket (unsuccessful) Pioneer III, which carried two Geiger counters, has yielded important information about the interplanetary value of cosmic ray intensity (Van Allen and Frank, 1959). Beyond 10 earth-radii the counting rate of the main counter was found to decline very slowly and appeared to have reached an asymptotic value at 17 earth-radii, the outermost point of observation. At this distance in interplanetary space, the counting gave the value of 3·6 cm^2/sec, as the absolute omnidirectional intensity, that is, the flux through a sphere of 1 cm^2 cross-section.

Outer Atmosphere Extension: Terrestrial Corona; Where does the Atmosphere End?

Satellite and rocket studies of the high regions of the atmosphere, as described in the preceding sections, all show that the outer atmosphere of negligible collisional frequency, lying above the lower atmosphere of significant collisions, extends to great heights Further, the terrestrial atmosphere is crowned, as it were, by the regions of trapped electrified particles extending to eight to nine earth-radii. In analogy with solar corona these regions may be called 'terrestrial corona'. The fact of the great extension of the outer atmosphere receives support from two other independent ionospheric investigations: Study of radio echoes from the moon and study of the 'Whistler' type of atmospherics. These are briefly noted below:

Echoes of radio waves returned from the moon were studied at the Jodrell Bank Experimental Station of the University of Manchester, England, by directing radio beams (frequencies 100 and 120 Mc/sec) to moon's surface (Evans, 1956-59). The echo records showed long period fadings This was ascribed to the magneto-ionic effect of the ionosphere (Faraday fading). From analysis of the fading data on two close spaced frequencies it was possible to compute the total electron content in a vertical column of unit cross-section. The results showed that during day-time, for most of the months, the number of electrons above the *F*2 layer maximum (that is, above about 300 km) was three times that below that level. This is possible if the ionosphere extends to great heights above the 300 km level.

The atmospherics are natural radio noise caused by highly damped electromagnetic waves produced by lightning discharge. A special type of atmospherics known as 'Whistlers' (from their peculiar descending tone) is caused by dispersive propagation of such very long waves (frequency only a few kilocycles/sec) propagated over very long paths. The long paths are provided by the magnetic lines of force of the earth rising to great heights and guiding the waves by the action of free electrons present in outer atmosphere (Storey, 1953, 1957). The waves originating in one hemisphere (say northern) are led by the lines of force to the magnetic conjugate point of the other hemisphere (southern) and, after reflection at the ground there, travel back to the point of origin. According to some recent analysis of 'Whistler' data made in New Zealand, the electron concentration needed in the outer ionosphere for the guidance has been estimated (Alcock, 1959) The concentration was found to decrease exponentially with height and, at a distance of 2,640 km from the earth's surface, it was found to be of the order 2 1 × 10^4 per cm . This is more than one order higher than the concentration at 2,450 km level as given in Table V.

The extension of atmosphere to such great heights demands high temperature, rising to several thousand degrees K, in the outer atmosphere. This raises the important question of the source of heat energy and of the heat balance of these high regions. It is sometimes supposed that the main source of heating above 100 km level is the absorption of hard electromagnetic radiation from the sun. But, the loss of energy by microwave radiation from the regions a little above 100 km, rich in oxygen atoms, far exceeds the input (Krassovsky, 1959). Further, there is continuous downflow of heat from the hotter upper regions to the cooler lower regions. There must, therefore, be source of energy other than solar electromagnetic radiations. Various suggestions have been made in this regard: Absorption of infrasonic waves from the troposphere, heating by the world-wide electric current systems (near 100 km level) generated by the so-called 'dynamo effect', and also heating by interplanetary gas which is a continuation of the solar corona having temperature of several hundreds of thousand degrees K. Though no firm conclusion has yet been reached, the last named suggestion due to Chapman (1959) has many points in its favour as being the dominant source. According to this idea the earth is immersed, as it were, in this hot interplanetary gas, and the downward flow of heat by conduction heats and expands the outer atmosphere to great heights. The extension, at a very modest estimate, is up to 20,000 km, more likely it is ten times greater. To the popular question: Where the earth's atmosphere ends? the answer today is that it does so where the density of the outer atmosphere falls to that of the interplanetary gas And, this occurs only at distances of some tens of earth-radii, perhaps at more than half the distance to the moon. The earth in its annual course round the sun carries with it through space this extensive system of outer atmosphere and the terrestrial corona

Concluding Remarks

India's Participation in Space Research Programme: Outer atmosphere and space exploration is at present pre-eminently in the hands of USSR and USA. Perhaps this is inevitably so. Few nations of the world can afford the men and money needed and can commandeer the necessary aids of highly developed engineering industries in the various branches of the applied sciences for a costly project like this. To give some idea of the cost: the USA budget for the satellite programme of the IGY was more than a hundred million dollars; for a five-year programme of satellite research £20 million was considered underestimate by Great Britain; and the design and construction of solar-cell alone of the American satellite Explorer VI has been a million dollars. Nevertheless, the state of affairs in which satellite programme is the monopoly of two nations only is undesirable. If allowed to continue, other nations will be in danger of being left permanently behind in this most fruitful field of modern research. From the trends of research efforts and developments, it may safely be predicted that manned flight, though still fraught with grave difficulties, will be a pacticable proposition within foreseeable future. It has recently been announced that the USA proposes to spend 700 million dollars on a research and development project with the object of bringing a man safely down to earth from an orbiting satellite. And, when this is successful problems affecting every nation will arise. The formation of the Committee on Space Research (COSPAR), under the auspices of the International Council of Scientific Unions, is therefore most welcome The Committee's function is to assist in carrying out fundamental research on an international scale with the use of rockets and rocket propelled vehicles. It has been reported that Great Britain is designing and constructing instruments for her space research plan and that the instruments will be carried by satellites launched by other nations In India we have enthusiastic groups of upper and outer atmosphere research workers Such groups have problems of their own If they can formulate the research problems clearly and can undertake the design and construction of the necessary instruments with the economy of space and weight as demanded, it may perhaps be possible for India to reserve, on behalf of such groups, space in satellites of other nations. Further, though a programme of satellite launching may be out of practical bounds for India, she can undertake high altitude rocket research programme. Such rocket programmes have been carried out successfully by countries other than USA and USSR. Expenses are modest and will be commensurate with the results obtained—valuable experience gained in the first step towards space exploration and collection of important research data. Rocket research is also of considerable interest to our Defence Research and Development Organization It is to be hoped that the Defence Organization and the Council of Scientific and Industrial Research will give serious consideration to sponsoring in our universities and research institutions studies and research in some of the more modest aspects at least of this fast developing field.

Finally, it is always open to our young research scientists to undertake theoretical work on the many ill understood features of the space and outer atmosphere: There are still gaps in our knowledge of the source of heat supply to the regions of high temperature of the outer atmosphere; the Van Allen radiation belts have still many mysteries; and an outstanding contribution will be a comprehensive theory co-ordinating the various inter-related geophysical phenomena controlled by the sun and the magnetic field of the earth, e.g., the auroras and their characteristic forms, the location of the auroral zone, the magnetic storm characteristics and their relation to the radiation belts

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MAN AND NATURE

S K Mitra

(delivered at New Delhi, December 1960)

Introduction

I consider it to be a great privilege to have this opportunity of presiding over the Anniversary Meeting associated with the Silver Jubilee Celebration of the National Institute of Sciences of India. It is fit and proper that I begin my address on this occassion with a brief history of the Institute founded with the object of promoting the knowledge of Nature including its application for gaining increased control for the welfare of Man with special reference to India.

In the year 1934, the late Dr M N Saha, following certain proposals made earlier by the Government of India, and in accordance with the wishes as expressed in certain resolutions adopted at meetings of representative scientists of the country, suggested, in the course of his Presidential address at the 21st Session of the Indian Science Congress at Bombay, that steps should be taken for the formation of an 'Academy' of Sciences in India. The suggestion was discussed in a special meeting of the General Committee of the Indian Science Congress, and a representative committee, called the Academy Committee, was set up to work out its details. The Committee worked for a whole year, overcame many difficulties, compromised many differences and submitted a detailed note on the constitution and the aims and objects of the proposed Academy under the title National Institute of Sciences of India. These were accepted, and, on 7th January, 1935, the Institute was founded at a meeting held in the Senate House of the University of Calcutta under the Chairmanship of Dr J H Hutton, President of the Indian Science Congress Association of the year. The Institute was inaugurated by Sir John Anderson, the then Governor of Bengal, and the inaugural address was delivered by the first President of the Institute, Sir Lewis Fermor. What Sir John Anderson, a noted administrator who had begun his life as a student of science, said on this occasion is worth recalling today: Said Sir John, 'I have never regretted the scientific training which I received during some of the most impressionable years of my life. I have not regretted it because I think that the detached outlook of the scientist may be an asset to an administrator. Conversely I think that a knowledge of practical administration must often be helpful to a man of science...'. This remark of Sir John Anderson—the desirability of the administrators having training in the scientific method and of the scientists in the administerial procedures remains as forceful today as it was a quarter of a century ago Nay, it is more so when the policy maker, the administrator, the scientist and the top executive have to work shoulder to shoulder, in close cooperation for economic planning and for the successful implementation of the planned projects.

As I have just said, the Institute was founded to function as an Academy of Sciences. The model of its constitution adopted for the purpose was that of the Royal Society of London The rules for election of Fellows are similar, and there is also restriction regarding the total number of Fellows to be elected (400). About ten years after the foundation (during 1943-45) the question of the recognition of the Institute by the Government of India as the representative body of scientists in the country was taken up. There were negotiations and discussions in which Professor A V Hill, the then Secretary of the Royal Society, who was in India at the time to advise the Government on the co-ordination of scientific researches in India with corresponding investigations in Great Britain, took active part. As a result, the Government, in 1945, decided to recognize the National Institute of Sciences as the premier society representing all branches of science in India. There were certain provisos, such as that the headquarters of the organization are to be at Delhi and that the Institute should have a Charter and should have statutory powers on the model of the Royal Society of London. The headquarters, which had been at Calcutta in the buildings of the Asiatic Society, were accordingly shifted to the Delhi University buildings From the year of this recognition the Government had commenced giving increased grants to the Institute to meet the expenses for publication, research fellowship, publication grants to scientific societies and other costs. A capital grant for its building was also sanctioned in the same year. In April, 1948, the foundation stone of its own building was laid by the Prime Minister of India, and its essential portion being completed in 1951, the Institute moved to its own premises. The Institute had also been informed earlier, in 1945, that the question of granting a Royal Charter had been 'taken up with His Majesty's Government'. However, on the country gaining independence soon, after, the matter was not pursued Another question, namely, that of the recognition of the National Institute as the adhering body of the International Council of Scientific Unions and of its allied organizations, was taken up with the Government in 1947. It is, however, still undecided. Very recently the Ministry of Scientific Research and Cultural Affairs wanted to know how the NISI may be developed on the lines of the Royal Society of London. Suggestions have been made in this regard and the matter is under consideration.

Science in India
The Council of Scientific and Industrial Research

What has been the progress of science in India in the 25 years since the foundation of the Institute? The progress can be gauged by the increase in the number of research laboratories, of research workers and of the scientific journals published in the country. A good index of the progress is the increase in the membership of the Indian Science Congress, the sponsoring body of the National Institute. Whereas the number of members (of all categories) enrolled in 1935, the year of inauguration of the Institute, was 907, that in January this year was 5,638, a sixfold increase.

Much of this increased scientific activity has been due to the support which scientific research began to receive from the Government with the establishment, in 1940, of the Board of Scientific and Industrial Research, which later became one of the component units of the wider organization, the Council of Scientific and Industrial Research. Indeed, the adoption of the policy of sponsoring and encouraging scientific research at the government level—though at the time it was 'actuated more by the urgent considerations of possible Axis aggression than to any national development'—was the greatest single event in the history of the progress of science in the country in the last quarter of a century. It is gratifying that the policy did not change with the cessation of hostilities It was rightly so, because, though the war had ended, the Axis combination of more powerful foes—poverty, ignorance and disease—remained. And, the combination could only be fought with the aid of science. The CSIR, therefore, very justifiably continued to exist, doing its useful work, sponsoring and helping scientific and industrial research and is now a wing of the Ministry of Scientific Research and Cultural Affairs.

It is to be recorded that the expansion of the activities of the CSIR, with its National and Regional Laboratories, Research Committees, and sponsored research schemes, research scholarships and research fellowships and grants for scientific publications, has been due almost entirely to the imagination and initiative of our distinguished Past President the late Dr S S Bhatnagar, with the active support of the Prime Minister.

I would take this opportunity of mentioning the names of two other past Presidents for their conspicuous work in connection with the most important of our national activities—Economic Planning. The late Dr M N Saha, for more than a decade before the launching of the First Five-Year Plan, had preached through press and from platform to educate the then Government and the public on the essential need of such planned effort for a backward country like ours. The contribution of our immediate Past President, Professor P C Mahalanobis, to the drafting of the Second Five-Year Plan and his continued association with the Planning Commission are well known. We may also note that our incoming President Dr A N Khosla is also a member of this body.

Progress in Science and Technology—Man's Control over Nature

It is interesting to recall today the state of science and of technology—Man's control over Nature—as it was 25 years ago at the time of the foundation of the Institute and to take stock of the progress made since then. A Physicist of 1935 could very well have said that the fundamental discoveries made since the closing years of the last century had already laid the foundation of the physical sciences and that further progress meant only filling odd gaps here and there. The claim was indeed justified. The four decades 1895 to 1934 gave us radioactivity and X-rays; relativity and quantum mechanics; photon, electron, proton and neutron; electronic structure of atoms and the physics of the molecules; cosmic rays and the expanding universe. Keeping pace with these discoveries in the physical sciences there were remarkable advances in the life sciences also: Discovery of vitamins, artificial parthenogenesis, carcinogens; development of bioelectric techniques for research and diagnostic purpose (ECG and EEG), Pavlov's conditioned reflex, Freudian psychoanalysis, and the beginning of a major breakthrough in the art of healing by the discovery of antibiotics. The decades also ushered in the air age and the radio age accompanied by revolutionary changes in the modes of transport and communication. The former followed the developments of internal combustion engine and the latter the invention of the thermionic valve. Distances measured in weeks could now be covered in days by air, whilst message-modulated electromagnetic waves could encircle the globe, via the ionosphere, in a matter of a tenth of a second. In the wake of these revolutionary developments came, as educator and entertainer, broadcasting, movie and talkie All these affected not only the everyday life of man, but also international relations. Truly, the world had become smaller.

These were formidable achievements indeed and could justly be called epoch making. Nevertheless even a cursory survey of those during the last quarter of a century shows that the discoveries and technological advances increasing Man's control over Nature, as made during this period, are no less outstanding The three great landmarks of progress during this period are, the inauguration of the atomic (or rather nuclear) age in 1945—inaugurated unfortunately by a demonstration of its destructive might only, the discovery in 1954 of the part played by nucleic acids (DNA generally and RNA in some cases) as carriers of genetical instruction and the advent of the space age in 1957 heralded by the launching of the first man-made satellite of the earth. According to many authorities, of the three, the second is the most important achievement of this age, far surpassing the other two in its potential effect on the future of the human race.

Besides, this period witnessed the development of new branches of science and technology and of new techniques for exploring nature and serving human needs. Thus have developed radio-astronomy and radio-telescopes; electron microscope and atom smashing synchrotons; radar and transistors; and cybernetics and automation. The last named, a child of Electronics (which acquired serious meaning only during this period), is ushering in a second industrial revolution The first revolution—which started some two hundred years ago—has freed man from the drudgery of manual labour by providing him with power driven machine; the second is releasing him from the bondage of many types of mental labour by endowing the machine with sensory complexes simulating the human brain And, in our everyday life, to mention only a few at random, have appeared the jet plane, television, magnetic recorder and the various kinds of plastics and insecticides. It has truly been said that we are living in an age of explosive progress in science and technology.

To what has this explosion been due? The exigencies of the two World Wars, specially the second one, has certainly been a great contributory factor. The Governments of the belligerent countries were vitally interested in the development of new instruments of offence and defence and they sought the aid of scientists and technicians for the purpose The scientific man power and the industrial resources of the respective countries were thus mobilized for research and development. The results obtained were beyond all expectation, and the lesson was learnt that fundamental research was at the root of all progress. This was not forgotten when the hostilities ended. Generous support continued to be given to scientific research, both by Governments and by many of the larger industrial establishments: the former because of its continued defence interests, and the latter, because such researches were expected to bring in rich practical dividend.

The second factor responsible has been the adoption of a policy of planned attack, supplanting largely the lone effort of individual scientific worker. Specific problems are now subjected to intensive study by research teams consisting of workers from many disciplines 'fusing their talents and techniques'. Chemists work in collaboration with physicists and mathematicians, biologists co-operate with chemist and physicists, and medical sciences requisition the aids of all the basic sciences and of the latest electronic and mechanical engineering devices.

Finally, it is not a one-way traffic—wherein science only promotes technology; technology in its turn reciprocates by providing new and powerful tools for experimental research. Science and technology, helping each other, have contributed significantly to the quickening of the pace of progress.

Man and Nature

Alongside of science, gaining greater and greater control over Nature, there is persistent effort to penetrate deeper and deeper into Nature to understand it and interpret it in all its aspects. However, in the course of this effort, by observation and by application of reasoning, the scientist has come to a stage beyond which he cannot proceed; this holds both in the case of the physical world and in that of the biological world. Boundaries of knowledge appear to have been reached which cannot be crossed. This is due not to any lack of experimental technique or to inadequacy of the dialectic tool but to the very nature of things inquired into. The situation has made the scientist face questions which belong to realms of metaphysics and philosophy. We find today top-ranking scientists concerning themselves with such questions as coexistence of the external and the internal world, the possibility of the natural laws being products of the human mind, relationship between the observer and the observed and that between mind and matter, and the criterion of certainty. It seems strange that a scientist whose job, according to popular conception, is to create and satisfy material needs through discoveries and inventions, should have to face questions of philosophy which were once thought to be mental exercises only.

I will take the liberty of making a few observations on the situation that has thus arisen and the attitude of the present-day scientists towards it. Let me first recapitulate briefly how limits have been set upon our knowledge in three widely different fields of scientific enquiry. The world of atoms and sub-atoms, the cosmic world and the world of life.

The atomic and sub-atomic world: In this world where space and time are measured in millionths and billionths of their respective units (centimetre and second), the limit is imposed by the famous Uncertainty Principle based on the experience that an observer cannot carry out any observation without disturbing the state of the observed object The observer with his equipment is, in fact, an inseparable component of the observed in any process of observation. As a result, it becomes impossible, even in principle, to make simultaneous precise measurement of pairs of quantities like position and velocity of a body for predicting its future state of motion. The limitation is of little consequence when the scale is large. But, for the atomic and sub-atomic world it becomes important and far-reaching. We cannot, for example, form a detailed picture of the motions of electrons round an atom. We have to remain satisfied with only a hazy picture representing our uncertain, probable knowledge. Take another example. A particle on one side of a thin screen, with two closely spaced holes in it, is found to be on its other side at a later time. In common parlance we say that the particle must have passed through one of the holes to the exclusion of the other. Such statement cannot be made if the particle is an electron. On the other side of the screen our working knowledge will be, it has passed through both the holes!

The indeterminacy of our knowledge also follows from a consideration of the well-known dual character of matter and radiation. Matter (electron), in one set of experiments, presents the picture of wave motion; in another set that of particles. So also is the case with radiation (photon). Each kind of picture is, however, incomplete in the sense that it does not give all the precise information necessary for predicting the future state of the entity—matter or radiation. Our knowledge of the state as gained from experimental observation is thus always indeterminate. The limit to which one of the two picture analogies may be 'pushed without contradicting the deductions as may be made from the other, leads to the mathematical formulation of the uncertainty principle.*

It should, however, be mentioned that the sacrifice of certainty and the limitations in our knowledge of details has its compensation also. To give one example, the fundamental principle that no distinction can be made between two electrons, when pursued logically with mathematical reasoning taking account of the consequences of 'indeterminancy', tells us how the two atoms of a hydrogen molecule are held together (Exchange Force).

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*According to Bohr the duality is not inherent in the photon or electron. It is the mode of observation, the experimental apparatus employed, that, depending upon its nature, makes the entity appear either as wave or as particle. No experiment has yet been devised by which both the pictures may be obtained simultaneously. The two pictures which they present are not contradictory, but complementary. Our difficulty in describing the situation arises in the limitation of our language which was invented to describe experiences not concerned with processes occurring within atoms. Only the things of which we can form mental picture, as a result of our daily experience, can be described by our language. A logical consequence of the 'complementarity' of the particle picture and the wave picture is thus, that it is not possible to assert categorically the state in which the fundamental entity (electron or photon) exists between two acts of observation. This means that we have to give up the idea of objective existence, say of electrons, independent of any observer. This extreme standpoint is not, however, favoured by Einstein's school.

The cosmic world: In the study of the cosmic world—space strewn with galaxies and their clusters—where distances are measured in hundred and thousand millions of light-years† and the evolutionary history in similar figures in years, the famous 'Red Shift' sets a limit to our possible knowledge of the Universe. Observations show that the more distant a galaxy or a galactic cluster is the redder it is. The interpretation of this strange result, according to the well-known Doppler Effect, is that the galaxies are receding, the velocity increasing with distance. Every increase in distance by a million light-year, increases the recession speed by about 30 km/sec. For a galaxy at a distance 10,000 million light-years, the speed is about that of light. The intensity of radiation received from such a galaxy is nil and, so far as a terrestrial observer is concerned, it is disappearing over his observable horizon‡. Our knowledge of the extension of the Universe in space and time is limited by this horizon—10,000 million light-years away. No increase of the power of the telescope will enable us to explore regions in space or epochs of time in the past beyond those fixed by this limiting figure.

Our possible knowledge of the future of the universe, and, generally of its large scale behaviour, becomes also limited if we accept the latest Cosmological Theory, the Steady-State Theory. According to this theory the matter disappearing over the'horizon' is being continuously replaced by creation of new matter. Combined with the 'homogeneity hypothesis',* the theory means that observed from any position in space-from another galaxy for example, or at any other epoch of time, past or future, the universe always presents the same picture: Space strewn in all directions with similar patterns of receding galaxies and galactic clusters, new galaxies forming out of matter continuously created, galaxies ageing and ultimately passing out of sight Nothing more can be learnt about the large-scale behaviour of the universe than we can learn from the position we occupy †

The world of life: In the world of life, the boundary of scientific knowledge still is what separates the world accessible to the senses, the external objective world, from that of feeling and consciousness within, the internal subjective world The boundary persists (its seat is in the brain of the scientific worker himself!) notwithstanding the remarkable advances made in new fields of the science of life, like molecular biology and brain-body relations. Living molecules have been discovered which produce their replica by duplication in suitable environment, chemical compound has been identified which regulates social life of certain insect communities (bees); physiological stimulation of certain brain centres has been found to bring into the realm of consciousness one's past experiences; it has been shown that one's mental make-up is dependent on circulatory hormones. and it is claimed that just as the physical sciences have given us control over the physical world, so the life sciences will one day enable us to control the internal world. We are nevertheless still ignorant of the nature of the psycho-physical coupling which transforms a nervous impulse ending in certain parts of the brain to conscious sensation, though, with the aid of modern electronic apparatus, we may trace the propagation of the impulse along a sensory nerve fibre from a receptor end-organ to the coupling point.

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†It is well to recall that a light-year is equal to $9{\cdot}5 \times 10^{12}$ km, that is, about 64 thousand times the earth-sun distance.

‡According to a recent report the farthest galaxy observed—with both optical telecope and radio-telescope—is receding at nearly half the speed of light. It is thus not far from the 'edge' of the universe.

*The 'homogeneity hypothesis' postulates that in the large-scale, ignoring local small-scale irregularities, the galaxies and the galactic clusters are homogeneously distributed. This, in other words, means that the universe as a whole is isotropic not only about our position but about any position. The former may be inferred from the finding that so general a property as the motion of the galaxies is the same for all directions. But, if the universe were isotropic about our position only, the terrestrial observer would be in a highly favoured position, at the centre of the universe as it were. This is very difficult to accept for philosophical reasons.

†As an alternative to the Steady-State Theory there is also the Evolutionary Theory. According to this theory, the universe was created some 10,000 million years ago with the explosion of a highly dense mass of matter—the 'primeval atom'. The receding galaxies are the result of this explosion. The theory may be justified mathematically. But it leaves one unsatisfied. How and when was the dense mass of matter created and what was the state of affairs before this creation? If matter could be created out of nothing once, why cannot it be so created continuously?

Consideration of these illustrations, drawn from three widely different fields of scientific endeavour, gives one the impression that Nature, under one pretext or another, refuses to give up her ultimate secrets. Why this should be so? The dogma that these are things too impious to search for, too wonderful to know is repugnant to scientific mind. A scientist today would rather agree with the view, held by many eminent men of his profession, that the basic assumption of scientific enquiry, that there exists a real world of matter and energy in space-time independent of the observer, does not perhaps represent the whole truth. The observer is perhaps an inseparable part of the world he is observing. He has stepped out of it only for the sake of convenience, to systematize his knowledge of what is outside of his self. He has thus unwittingly and artificially dichotomized Nature into an internal subjective world and an external objective world He now wants to step back into it t have a closer view. The result is confusion part trying to understand the whole. I is easy for the scientist today to agre with the philosophy that Man is one wit Nature, that mind and matter are onl different facets of a single reality and tha if the laws of the external world ar creations of the human mind, the exis tence of the human mind require indispensable partnership with Nature.

The Future of the Institut

In concluding my address I would lik to remind the Fellows that of the 12 Foundation Fellows with whom the Institute started in 1935, only 42 are in th land of living today. They all—and happen to be one of them—rejoice o the Institute completing its 25 years fruitful existence. The future of th Institute now rests with the younge generation. This is as it should be. A individual's life is limited, an Institution' need not be so. It may remain perpetuall alive, being ever rejuvenated by the infusion of youthful blood. I am sure ou youthful Fellows on whose efforts an activities the future growth of the Institute depends are alive to the fact tha we are living in an age of scientifi revolution when application of scienc and technology to the welfare and economic progress of a nation is a vital issu and when, as never before, there is urgen need of strengthening the activities of a institution like ours. They will, I hav no doubt, spare no pains to do an perform all such 'acts, matters and thing that may assist in, conduce to or b necessary for the fulfilment of the aim and objects of the National Institute'.

Dr Ajudhia Nath Khosla, FNA*

(Elected to the Fellowship, 1951; President 1961-62)

Dr A N Khosla, former Governor of the State of Orissa (1962-68), was born on December 11, 1892 at Jullundur, Punjab. He graduated in Engineering from Roorkee University in 1916 and later received Doctoral degree in Engineering (*h. c.*) from Rensselaer Polytechnic Institute, USA, Roorkee University and Doctorate in Science (*h c.*) from Sambalpur University. Dr Khosla was the Chief Engineer, Irrigation Branch, Punjab and Secretary to Punjab Government, (1943-45), Consulting Engineer, Government of India and Chairman, Central Water and Power Commission and Additional Secretary, Ministry of Works, Mines and Power, Government of India (1945-53), Special Secretary to the Government of India (1953-54), Vice Chancellor, Roorkee University, 1954-59, before joining as Governor of Orissa State in 1962 He was a Member, Rajya Sabha (1958-60) and Member, Planning Commission, Government of India (1959-62), Hony Life Member, Institution of Engineers, Member, American Society of Civil Engineers, Member, American Concrete Institute and Chairman, Board of Consultants of Bhakra Board, Sabargiri Board, Beas Board, Balimela, Yamuna Board, Maneri Bhali Board and Ram Ganga Board till 1975. Dr Khosla has received S S Bhatnagar Medal (1975) and was conferred the titles of Padma Bhushan (1954) and the Padma Vibhushan (1977).

Dr Khosla has contributed to the researches in levelling across rivers (invented the Khosla Dist), researches in concrete, reinforced concrete and precast units; hydraulics, particularly flow of water in porous sub-soils, designs of weirs on premeable foundations and uplift pressure under dams; researches in silting of reservoirs, and also in runoff-rainfall relationship and flood intensities.

Besides this he has carried out investigations for Bhakra Dam Project, the Headworks of the Sutlej Valley Project; established River Discharges Division; constructed Suleimanke barrage and Trimmu-barrage; reconstructed Khanki barrage; carried out large scale drainage and reclamation works and prepared several other storage and power projects in Punjab.

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*Address. 15 Jangpura 'B', Mathura Road, New Delhi-110 014.

SCIENCE AND ENGINEERING

A N Khosla

(delivered at Cuttack on January 1962)

It is a rare privilege for me to preside over the Anniversary Meeting of this premier Institute of Sciences of India I have had the opportunity of presiding over a number of national and international engineering institutes, associations, conferences and boards and also some scientific bodies like the Engineering Section of the Indian Science Congress, the Central Board of Geophysics, the Fifth Congress on Theoretical and Applied Mechanics, but this is the first opportunity for me to address a gathering of the foremost scientific talent of the country, including engineering

I happen to be an engineer by training and by profession I have had opportunities for carrying out research in engineering and related sciences, notably in the field of flow of water through subsoils in relation to the stability of structures founded on permeable soils. Other researches pertained to levelling of precision across wide expanses of water or widely separated mountain peaks, rational concept of run-off as residual of rainfall after making allowance for evapotranspiration loss expressed as a function of mean temperature; long-span roofs of the order of 500 ft without intermediate supports made up of 3 in thick reinforced concrete precast trough units, etc., but I must confess that, while some of my work may rank as classical and constitute an original and significant contribution to engineering, my achievement and contribution in the realm of pure science can only be considered as relatively insignificant.

I have made this plain confession to highlight the generosity and spirit of accommodation of the Fellows of the Institute in electing me their President despite my limitations, the all-embracing character of this National Institute and finally the oneness of science and engineering

I understand it is customary for the President to take for his Anniversary Address a subject of his specialization in which, by virtue of his deep study and research over the years, he has acquired special competence and expert knowledge But I propose to make a departure from tradition and talk on a subject which, though not in the field of my specialization, is nevertheless within my purview as Member, Planning Commission for Education and Scientific Research This subject is Science and Engineering It is of fundamental importance for the successful implementation of the Third and subsequent Five-Year Plans and for the achievement of the ultimate goal of all scientific progress, namely, the spiritual and material advancement of the human race.

I am convinced that science and engineering are only different facets of the same entity and that the somewhat common misunderstanding among us that science and engineering are two different entities must go, if science in this country has to make its full contribution in the development of our human and natural resources Basic research leads to new knowledge It provides scientific capital. It creates the fund from which the practical application of knowledge must be drawn Basic research is also the pace-maker of technological research Science creates new ideas. Engineering, faced with unsolved problems, demands knowledge and this stimulates further scientific investigation. It also provides new tools, materials and techniques for science and for the exploitation of previous scientific breakthroughs. The interplay of science and engineering, of discovery and invention, have brought about the evolution of machines and techniques to meet and provoke the demands of modern society. The steam engine, for instance, is a product of science but science, in turn, owes much more to the steam engine, because of the stimulus provided by it to thermodynamics. ‘New discoveries like Faraday’s electromagnetic induction brought into being new industries and new techniques; applied mathematicians like Rankine and Lanchester did much to remove empiricism from engineering design; and new inventions like Parson’s turbine and Whittle’s jet engine changed fundamentally the path of development. It made possible the huge generators we use today with manifold economies. Faraday’s theories based on experimental researches were given form and precision in Clark Maxwell’s electromagnetic theory, which prompted Hertz to investigate resonating circuits, the starting point of radio communication’ The discoveries by J J Thomson and Rutherford ‘of the electron and the nuclear atom opened new vistas. The science of electronics with Fleming valve and Appleton’s discovery of the ionosphere led on to the development of radar and eventually to radio astronomy.’ Electronics has provided industry with devices swifter and more accurate than the human senses and made possible the modern computer which, with its speed and memory, has intensified so much the power of the human brain. The development of the nuclear reactor has removed any fear that the world may be short of energy in the future. The space ships, the atomic power plants, solar batteries, transistors, means for desalting sea water, etc., are other examples of the interplay of science and engineering. Taken together, these two aspects of research, science and engineering are the mightiest force in human advance.

Research investment in the scientifically and technologically advanced countries has been growing at an exponential rate, this growth being maximum during and since World War II. The USA’s total expenditure in 1961 for science and engineering education and for basic and applied research is about $10 billion (nearly 4,800 crores of rupees) or approximately 2 per cent of the $505 billion gross national product. This is made up of:

Science and engineering education	(a)	high school level	$2 6	billion
,,	(b)	college and post-graduate level	$2 1	,,
research	(a)	basic	$1·8	,,
,,	(b)	applied	$3·2	,,
		Total	$9·7	,,

The anticipated expenditure on scientific and technological research in the Third Five-Year Plan of India is about Rs. 200 crores, or Rs. 40 crores per year, or 0 21 per cent of the Rs 19,000 crores national product in 1965-66.

With the growing pace of development of natural resources and industry, the need will be increasingly greater for a pattern of engineering education which has an integrated course content of engineering and basic sciences, more particularly mathematics and physics. Our aim must be to find new knowledge through basic research and prepare future scientists and engineers through science education. In our scheme of teaching, it should not be so much the passing on of established truths as showing the way to criticize and discover new truths, the emphasis being on discovery rather than knowledge. Science education and technology are interlinked. Improvement of one raises the quality of the other.

The aim of science is to know and understand the ways of the universe—‘from the forces in the atomic nuclei to the motion of stars, from the growth of a living cell to the functions of the brain, from the measured responses of man to the dynamics of social organization’.

The foundation of scientific progress is the college and postgraduate education of scientists and engineers and the research that is integrated with that education; and these latter have as their base all that is taught in elementary and high schools, particularly in mathematics and science.

Advancing technology has transformed life in Europe, the USA, and the USSR and has helped these countries to achieve the highest standards of living. Machines have relieved man of drudgery and freed him for less arduous tasks and far greater leisure. Mechanization and use of fertilizers have increased the productivity of the farm. The average life span has risen to almost 70 years as a result of advance in medical sciences.

But technology cannot advance except through interaction with science The engineer increasingly meets problems which can no longer be solved through empiricism. The trial and error approach of the past is too slow and too costly and may involve risk of failure. So he must turn to science With the new information from science and existing technology, the engineer will be in a position to progressively solve most problems. The broader understanding of science speeds development, cuts the lag between idea and product The greater the pace of technological advance, the greater and more frequent the need for science.

Scientific talent is a scarce resource Every young person who shows desire and the capacity to become a scientist should be ensured the opportunity to do so and every scientist who is prepared to make and is capable of making scientific contribution should be ensured the opportunity to do so. Our aim should be superior quality and not mere numbers of our scientists and engineers. This can be achieved through superior teaching. High intelligence alone will not ensure quality. Success further requires creativity in conceiving new ideas, ingenuity in devising new techniques and experiments, vigour and tenacity in pursuing new ideas and experiments to the very end.

Science and technology have made progress at a fantastic pace during World War II and have registered tremendous advances in all fields of human interest. More spectacular among these are the advances in nuclear science, space research and earth satellites. Of the scientists that have brought about the present status of development in science and engineering, some were pure theorists who worked with and dug deeper into the basic concepts of science. There were others who, in addition to theory, explored and experimented. There were still others who spent most of their thoughts and time in a laboratory, proving things, developing things and bringing the theorist's theories closer to reality. These latter were the realists of scientific fraternity And then there were the engineers who consummated the research effort into physical reality and brought into being the modern offspring of science, such as automation, transistors, computors, television, submarines, earth satellites, space ships, and so on

Organized research in pure science in India has been in existence for over a quarter of a century Research in engineering, except in the field of hydraulics, is, however, of recent growth. By and large, we are still living on the discoveries and inventions of other nations. Due to political dependence before 1947, we made a late start in scientific research and that too in the abstract without any incentive to translate its results into concrete physical reality. Engineering research started still later and much after independence.

A chain of National Laboratories, the Atomic Energy Establishment, Defence Science Laboratories, various departmental research laboratories, research centres and schools at the universities and some private research organizations have sprung up since independence; but there is insufficient co-ordination of research, firstly, between the various research activities, secondly, between the national laboratories, departmental laboratories, the universities, other research organizations and industry, and thirdly, there is insufficient liaison and understanding between pure scientists and engineers. There is considerable lag between scientific discovery and its utilization for production. If India has to catch up and be reasonably self-sufficient in relation to her needs in science and technology and has to be in a position to contribute to world knowledge in keeping with what she receives out of that world pool, there must develop among scientists, engineers and politicians a sense of awareness, of urgency and of purposeful action. The lag between discovery and production has to be cut down. There has, in effect, to be some sort of a 'crash programme' as in a war emergency—a type of approach where research is entrusted not to a few experts but to hundreds, in teams, so that many difficult lines of investigation can be followed simultaneously and things scientific can be accomplished in a fraction of the time normally required. In other words, we have to move forward from the abstract to the concrete and from the individual to team action But in all this, we must make sure that the basic requirements of independence and objectivity of the scientists are scrupulously respected. We are no longer in a position to wait for things to happen in the routine course—we have to force the pace, define objectives, formulate programmes and take vigorous and sustained action to achieve their implementation.

Such a 'crash programme' was successfully carried through during World War II in the USA under the purposeful and dynamic guidance of Dr Vannevar Bush as Director of the Wartime Office of Scientific Research and Development Dr Bush, known as a scientists' scientist, was a scientist, an engineer and an administrator, all rolled in one

'Dr Bush fathered and guided the War Science programme so well that, for the first time, research was put on a highly co-ordinated basis. The work of at least a decade was compressed into the three and a half war years. Duplication of effort was greatly reduced. Instead of many scientists working independently in many directions towards a single solution, a problem was split up and a crew of experts, each in the top of his own specialized field, worked on portions of it towards a co-operative result. The research varied from jet planes and new medicines to radar and atomic energy.'

Vannevar Bush was science's skilled organizer with thirty thousand physicists, chemists, engineers and doctors under his direction. He achieved spectacular results despite the persisting prejudices against scientists and the petty professional and political jealousies.

Born in 1890, Dr Bush graduated in engineering from Tufts in 1913 and got his Doctorate in engineering both from Harvard and MIT. During World War I he perfected the submarine-detecting device. He made many important contributions to science and engineering. In the 1920's he developed a miniature power network analyzer and in 1935 MIT's advanced differential analyzer, the giant electronic brain, which later helped solve many of the wartime problems in atomic physics, acoustics, ballistics and structures. In him, nature has seen fit to compound harmoniously many elements—science, engineering and more than that, those human characteristics which command the respect, admiration and loyalty of his co-workers.

I have dilated on the story of Dr Vannevar Bush, because he combines in himself the best that is in a scientist, an engineer and a man, and because the way he organized science to do the wartime job assigned to him is the one way which scientifically and technologically backward nations must follow if they mean to catch up.

Dr Atma Ram in his Shanti Swarup Bhatnagar Memorial Lecture delivered at Delhi on 6th October, 1961, On the Making of Optical Glass in India, drew pointed attention to the phenomenal success in the 1880's of the German venture 'Jena Optical Glass' as a result of the close collaboration between science and engineering through Ernest Abbe, the physicist, Otto Schott, the chemist and glass-maker; and Carl Zeiss, the optical instrument manufacturer. In contrast, he mentioned the failure, in the same period, of the British venture of optical glass-makers for lack of such collaboration between the scientist and the glass-maker, both of whom, while striving for the consummation of their long researches, failed to achieve results because of lack of collaboration

This again demonstrates that science and engineering must be harnessed in full collaboration, if science and technology are to take a real jump forward and make effective contribution to the economic growth of the country.

It is only through science and engineering that modern society can hope to advance, attain higher living standards and a fuller life. But are we doing enough in this direction and following the line of action which will ensure achievement of our planned objectives?

The Scientific Policy Resolution of 4th March, 1958, with the approval of the Parliament, became the basic document of national scientific policy for the support and encouragement of science education, scientific research, technology and training of scientific and technical personnel. Sections 6 and 7 of the Resolution read as follows.

'6. Science has developed at an ever-increasing pace since the beginning of the century, so that the gap between the advanced and backward countries has widened more and more. It is only by adopting the most vigorous measures and by putting forward our utmost effort into the development of science that we can bridge the gap. It is an inherent obligation of a great country like India, with its traditions of scholarship and original thinking and its great cultural heritage, to participate fully in the march of science, which is probably mankind's greatest enterprise today.'

'7. The Government of India have accordingly decided that the aims of their scientific policy will be—

(1) to foster, promote, and sustain, by all appropriate means, the cultivation of science and scientific research in all its aspects—pure, applied and educational;

(2) to ensure an adequate supply, within the country, of research scientists of the highest quality, and to recognize their work as an important component of the strength of the nation;

(3) to encourage and initiate, with all possible speed, programmes for the training of scientific and technical personnel, on a scale adequate to fulfil the country is need in science and education, agriculture and industry and defence,

(4) to ensure that the creative talent of man and woman is encouraged and finds full scope in scientific activity,

(5) to encourage individual initiative for the acquisition and dissemination of knowledge, and the discovery of new knowledge, in an atmosphere of academic freedom;

(6) and in general, to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge '

'The Government of India have decided to pursue and accomplish these aims by offering good conditions of service to scientists and to accord them an honoured position, by associating scientists with the formation of policies, and by taking such other measures as may be deemed necessary from time to time.'

This Scientific Policy Resolution sets forth in clear terms India's problems and objectives and the steps the Government have decided to take in achieving these objectives. Among others, it assures to the scientists good conditions of service, academic freedom and an honoured position by associating them with the formulation of policies.

The two giants of science and technology today are the USA and the USSR The USSR is said to be somewhat ahead in the content of science teaching in the high schools, in the wide coverage in numbers, in liberal provision of funds and in improving the conditions of work of scientists. The USA has taken quick note and is making adjustments. Both countries are encouraging initiative and freedom of action in matters concerning science and technology. India can with profit take lessons from the direction in which the energies and resources of these two giants are being channelized.

In the USA, it is recognized that science, and science education starting from the high school, are of vital importance in the growth of the nation and that the teaching and course content must undergo frequent review for up-to-dateness. They also recognize that the wisdom with which science is brought to bear upon the problems of coming years will determine, in large measure, the future of the nation, and further that a nation which depends on others for its new basic knowledge will be slow in its industrial progress and weak in its competitive position in the world trade, regardless of its mechanical skill.

It is also recognized that the simplest and most effective way in which industrial research can be strengthened is to support basic research and to develop scientific talent. Colleges and universities must furnish both new scientific knowledge and the trained research workers It is through basic research in biology, biochemistry and other sciences, for example, that solutions of major disease problems are to be reached. It is wholly probable that progress in treatment of cardio-vascular disease, renal disease, cancer and similar refractory diseases will be made as a result of fundamental discoveries in subjects unrelated to these diseases and perhaps entirely unexpected by the investigator.

Economic growth and development of new products in industry are dependent upon rich resources of basic knowledge in relation to methods and techniques of basic research essential to training and full development of skilled research investigators

During the Second Five-Year Plan, there were set-backs and gaps in the implemention of the Plan in the vital sectors of industry, power and transport mostly as a result of shortage of foreign exchange and technical know-how. The priorities in the Third Plan, apart from agriculture, are for basic industries, power, transport and their essential complements—technical education and scientific and technological research. Adequate provision has been made in the Plan for technical education but not enough for science education or basic and applied research. Unless science teaching improves and catches up with up-to-date developments, and indigenous basic research provides increasingly new knowledge, our progress of basic industries is going to be slow and expensive mainly because of lack of adequately equipped scientists and engineers in required numbers and of lack of specialized knowledge. Industry can fully meet internal demands and provide goods for export at competitive rates only if bulk of the raw materials, technical skill and basic research are of indigenous origin. It will, therefore, be necessary in the Third Plan to lay special emphasis on science teaching, technical education, research and co-ordination of research, and on cutting the lag between discovery and its utilization. It will be necessary to co-ordinate more effectively the various research activities, the work of the national laboratories, the atomic energy establishment, departmental laboratories, universities, private research organizations and industry and in particular to encourage basic research in universities. The training of scientific research workers will have to be given high priority.

Indian science and technology have already started achieving results in various fields of industry. The development of stainless steel out of indigenous materials, the manufacture of optical glass with techniques and materials exclusively developed in India, of electronic instruments and isotopes, the utilization of low grade coals for metallurgical purposes and of industrial and agricultural wastes and the development of several new processes and techniques are a significant contribution to the industrial and economic progress of the country. But all said and done, we have only touched the fringe of the problem.

The National Institute of Sciences is presumed to be the nerve centre of science in India It can and must play a positive role in recommending policies and directing research towards concrete achievement in the shortest possible time. For this purpose, science and engineering must advance side by side, each one enriching the other, so that discovery leads to production without lag The Institute has to ensure up-to-dateness in everything relating to science and engineering education and in basic and applied research, through a carefully planned programme of documentation and literature exchange with national and international scientific bodies.

The International Geophysical Year of 1957-58 and the International Conference on the Peaceful Uses of Atomic Energy are two impressive examples of international co-operation in science and India has been an active member in both It may be in the common good if nations could agree and co-operate on the scientific and practical aspects of Outer Space research

India may consider the appointment of Scientific Attaches to our selected Embassies, say in the USA, the USSR, Canada, Germany, France, Switzerland, Japan, etc., so as to remain informed of latest developments in the fields of science and engineering education and basic and applied research. A Scientific Attache has already been posted in the UK.

Advancement in science and technology will be rapid or slow depending on the number of really first class men who are engaged in the work in question. So in the last analysis the future of science in this country will be determined by our basic educational policy. We must ensure improvement and up-to-dateness in the teaching of science. We must evolve programmes to provide to gifted students at the graduate, undergraduate and secondary school levels research experience and educational opportunities far beyond those offered by the normal curriculum and to ensure that those with special aptitudes and ability, from whatever walks of life, have the fullest opportunity for the realization of their talent.

For the young research worker, we must make sure that his talent and potential for creative work are not suppressed or hampered by hierarchy or bossism and that he gets full credit and recognition for original and creative work Originality and creativity are not the monopoly of advanced age and long experience They can equally be the privilege of younger people, if they are given the opportunity and the scope for the development of their potential talent.

We have many young Indian scientists of outstanding talent scattered over Europe and America, holding responsible positions in universities, research organizations and industry, who would willingly return to serve their motherland if they can be assured of opportunities for research and creative activity in an atmosphere of scientific freedom. We should take all possible steps to utilize the exceptional experience and talent of these young scientists

In conclusion, I would like to refer to one of the greatest mathematicians of the world, Ramanujan, called by G H Hardy 'the most romantic figure in the recent history of mathematics', who, although failed to pass the First Arts Examination of an Indian University, became a Fellow of the Royal Society (the first Indian to be so elected) in 1918 at the age of 31. He died in 1920 at the age of 33. To perpetuate the memory of this great genius, the National Institute of Sciences of India has decided to institute a gold medal, which will be awarded every alternate year to an eminent scientist—Indian or foreign. May his memory inspire us in our search for truth and knowledge!

NATIONAL INSTITUTE OF SCIENCES AND THE PRESENT EMERGENCY

A N KHOSLA

(delivered at Delhi on December 30, 1962)

Today we are meeting under the shadow of a grave emergency brought about by the unprovoked, treacherous and wanton invasion by the Chinese on our northern frontiers. Ours have been a policy of peace, with friendship towards all and ill-will towards none. We have befriended the Chinese these last 15 years and upheld their cause at the United Nations. We had sincerely believed that the absence of friction, which characterized the relations between the two countries for over two thousand years, was a guarantee of continuing good neighbourly relations This sudden and mad venture of the Chinese expansionists has, therefore, come to us as a shock and a disillusionment The treachery, the surprise and the massiveness of the Chinese attack and the initial reverses we have suffered have, however, been a blessing in disguise The country has been welded into one almost overnight It has evoked instantaneous response among the people, steeled their will and resolve to throw out the invader, and demonstrated the basic unity and character of the people. The stories from the battlefield have brought out in epic relief the wonderful stamina and heroism of our Jawans. Unprecedented enthusiasm has been generated among the entire population, men, women and children, all of whom are anxious to do their utmost and are prepared to make any sacrifice to maintain the freedom of the country. A new sense of urgency is in evidence everywhere. The first task now is to give a purposeful direction to this spontaneous upsurge of enthusiasm, sense of urgency and spirit of sacrifice.

We have now realized that firstly the Himalayan borders no longer offer us the security which, we felt, they did all these centuries; secondly, that military strength with deterrent striking power is the only answer to any kind of insecurity in the present state of an imperfect world and, thirdly, that we have to be in a state of preparedness all the time. We must create and keep in readiness a strong and organized army well equipped with the most modern weapons and striking power

The Indian soldier is among the best and the bravest in the world We have never lacked courage, but we have been lagging behind in science and technology and their essential base, education Modern military power rests mainly on science and technology, but it must have at its back the efforts of the whole people in the field, in the factory and in the transport of the products of the field and factories to the front lines and to the civilian population. Science and technology are the key to better and more production in agriculture, industry and war weapons.

We have to remember that for the effective and continuing defence of our country, we have to strengthen our own military, industrial and agricultural base and prepare ourselves to defend the country with our own resources of men, food and industrial output and our own equipment Also, our military might must be such as to provide an effective deterrent to any aggressor like the Chinese expansionists, who may be tempted to embark on a similar mad adventure in the future. We may and we must gratefully accept all help in arms, ammunition and technical know-how from friendly countries during the present emergency, but that cannot be a continuing affair. We must build up our own military potential and know-how. We have also to remember that the present emergency may last for several years.

We cannot expect others to come and defend our freedom

What can we of the National Institute of Sciences do to help in building this agricultural, industrial and military base and keeping scientific and technological developments up to date?

The Council of the Institute has, on behalf of the National Institute, already submitted its Resolution to the President and Prime Minister, placing at their disposal their scientific knowledge and all other resources We have now to consider ways and means of giving a practical shape to this Resolution

In my last anniversary address I mentioned that Science has two facets, namely Pure Science and Applied Science or Technology, and that the interplay between these two was responsible for all the modern discoveries and their translation into concrete realities for the benefit of mankind. Research in pure science leads to new knowledge, but new knowledge to be useful and to be able to add to human well-being has to be given concrete shape. Basic research creates new ideas. Engineering research translates these new ideas into new machines, new techniques and new processes In that process it meets new problems which again demand further basic knowledge and thus stimulates further scientific investigation. This inter-play of science and engineering goes on and results in mounting developments of still newer ideas and newer techniques and instruments. The evolution of isotopes, nuclear power plants, space ships, solar batteries, transistors, computers, etc , has been the outcome of such inter-play.

Research in pure science is relatively inexpensive. The major expense, according to the experience in the USA, the USSR and elsewhere, is in the research for its application, basic research accounting for about 5 per cent and applied research for the remaining 95 per cent of the total outlay on over-all research. In the modern age science and technology have become a decisive element in the fall or survival of our very civilization. The simultaneous development of pure science and technology is, therefore, the only way by means of which the scientists and engineers can faithfully discharge their social responsibility to the nation.

The inter-play of science and technology assumes over-riding importance in an emergency like the one facing us at present In peace time a nation can wait in patience for the evolution of abstract ideas and their leisurely translation into concrete achievement But in war there is no time to wait Discovery and application must advance together and be of immediate as well as of progressive use in the war effort.

During World War II, which witnessed the greatest advancement in the fields of pure science and technology, the scientific organizations in the various countries involved had to do a good deal of rethinking and reorganization The scientifically advanced nations consisted of democracies like the USA and the UK and dictatorships like the USSR and Nazi Germany The two dictatorships reorganized science and technology and conditioned their aims and developments to suit their social and military objectives—one to further its political ends, and the other to spring on the world a thoroughly well prepared war. When the war actually broke out, the need for reorganization of science and technology became apparent to the democratic countries of Great Britain and the USA and both countries acted quickly.

In both these countries science played a decisive role, not only in the highly specialized fields of warfare and production, but also in almost all phases of civilian and social life, in feeding and clothing the people and in keeping them healthy.

The common danger brought about the release of the most secret developments of one country to the other and secured a scientific liaison between the USA and the UK. This was a healthy development not only for the prosecution of the war, but as the first serious indications of scientists disregarding narrow national limits in the interest of the higher objective of world peace.

The outbreak of war changed the attitude of America, the arsenal of democracy, which brought about awareness that unless science and technology were recognized and canalized under a planned programme, and all the resources of Government scientific establishments, research laboratories and industry were pooled together, quick results would not be possible.

Accordingly a crash programme was initiated under the purposeful and dynamic guidance of Dr Vanneevar Bush as the Director of the War-time Office of Scientific Research and Development. Dr Bush fathered and guided the War Science programme so well that, for the first time, research was put on a highly co-ordinated basis. The work of at least a decade was compressed into three and a half years. Duplication of effort was greatly reduced Instead of many scientists working independently in many directions towards a single solution, a problem was split up and a crew of experts, each tops in his own specialized field, worked on portions of it towards a co-operative result. The research varied from jet planes and new medicines to radar and atomic energy. Dr Vanneevar Bush, a Doctor of Engineering, from both Harvard and MIT, organized science to do the war-time job assigned to him, and he made a success of it.

In India due to lack of industrial development, backwardness of technology and the static nature of economy, science remained largely an exhilarating hope rather than a field for proud achievement. The World War, however, brought about a change even in the Indian science. Many advances were made in the field of chemical research, notably the evolution of solid fuels to emit intense heat for a period of time, fabrics and other materials resistant to poisonous gases, processing of cloth to give insulating properties and warmth of wool, etc Some of the Indian scientists abroad at that time were responsible for the invention of the deadly 'flame throwers' and researches in chemical warfare and treatment of tropical diseases

The goal of defence science is technical superiority in men and machines The last war witnessed the emergence of thousands of inventions of military interest The science of explosives made undreamt of advance with the discovery of 'chain reactions' It was found possible to rearrange the atoms of solids in such a way as to make them far stronger than steel or any other substitute yet known This had a special significance for aeroplane construction The pride of place, however, goes to radar, a British invention It is this which made Germany lose the 'Daylight Battle of Britain' Radar has revolutionized peace-time communications and navigation and has given rise to a new industry known as electronics The pilotless plane, the gyro-flux compass, the jet-propelled plane, had their origin during this war and in its midst. The U-boat submarine detective devices, the degassing girdle that rendered the mines completely innocuous, were also the offspring of science and technology during this period.

Science and technology also helped to solve the many supply problems. Quick movement is the essence of action in modern wars, and weight is the greatest handicap to such movement. Also, troops have to be fed well, kept clean, and the casualties among them restored. A modern war cannot be won on the battlefield alone. It is first and foremost a battle of supplies and production. All these problems were tackled by the scientists and technologists with conspicuous success. The problem of short supply of materials was solved to a great extent by salvage and substitute. All used-up material was brought to the scientist and he gave it a new lease of life. Metals, rubber, old paper, card-board, textiles, rags, ropes, strings, shavings or dust, bottles and glass, bone and food scraps, containers and an inexhaustible list of socalled waste material was reprocessed and converted into useful material. Substitution was as important as salvage. The most sensational productions of substitution were light metals and alloys, synthetic meat of every known variety and taste which had a vegetable base, the improved dehydration process in the field which compressed full meals to the size of pills and tabloids 'Plastics' covered a whole series of substitute industries like artificial silk, rayon, nylon, the new outfit for paratroopers, which is a marvel of lightness, compactness and comfort.

A new science of electronics developed during the war It is a steady and technological application of the electron, one of the three basic ingredients comprising the atom, the other two being proton and neutron. The electronic valve of the radar, the modern computer, television, nuclear power are the products of this new science.

The war-time medical advance was equally spectacular. The development of safe and easy blood transfusion technique, the discovery of the water part of the blood called the plasma, the sulphonamides, penicillin and civicillin and various other new means of removing the danger of infection, improving the healing properties and prolonging life, came about in the same period Malaria, typhoid, diarrhoea which claimed the highest toll in army life, were substantially controlled and the Second World War was called the best and cleanest war ever fought. The medical discoveries made in the course of the war were legion and many of these discoveries were made not in the sheltered laboratories removed from the field of battle but in the laboratories of the battlefield themselves.

The joint efforts of the democracies succeeded in solving many seemingly baffling problems and conjured up a whole series of new industries which have since revolutionized production in the post-war era. Their victories on the medical front were such that the world will forget the slaughter of the war and will remember the great blessing of health and healing that these have bestowed upon mankind.

I have mentioned at some length the achievements of scientific and technological research during World War II to highlight the importance of need for rethinking and of reorganizing research activity in the country with a view to putting research in India on a highly co-ordinated basis It is only then that we can hope to accelerate the pace and achieve results in time to meet the mounting requirements of our defence. In this context there is urgent need for considering how best the National Institute of Sciences, which has as its Fellows almost all the top scientists, though not yet all the top engineers of India, can fit into the scheme of reorganization for research on such a highly co-ordinated basis

A large number of Fellows of the National Institute are already serving the nation in different capacities But full use is not being made of the entire scientific talent in the country. There is enough of talent and no end of enthusiasm, but the scientific set-up appears to be such that talent in most cases does not find the opportunity or the climate for its full play, with the result that the scientific effort in the country, which is of no mean order, is not producing commensurate results

Our scientists still crave for acceptance of their papers outside for publication rather than in India and place greater value on encomiums abroad. At the same time there is halting recognition from within the country so that the urge for original and creative research gets damped. If indigenous talent has to produce results, as it must if the country has to stand on its own, particularly in matters of defence, then there must be a radical overhaul of our entire scientific set-up

Since the Chinese invasion of our country on 20th October last, Government has done a good deal of rethinking and some reorganization. But perhaps something much more is needed to enlist the active, creative and constructive effort of the large reservoir of scientific and technological talent of the country in the prosecution of research on a highly co-ordinated basis

This is where the National Institute of Sciences can play a really effective role As a first step, I would suggest that a small Advisory Board should be set up for the purpose of locating problems, assessing research potential, individual as well as laboratory or organization wise, and co-ordinating research activity throughout India, with special emphasis on defence requirements Such an Advisory Body should be kept fully informed, by the authorities concerned, of the many problems as they arise during the emergency. The Advisory Body may, on its own initiative, discover some of these problems It should then proceed, with the full backing of the Government, to arrange for the expeditious solution of all such problems

This Body may have the following responsibilities:

(1) To give advice on such scientific problems as may be referred to it by the Central Government.
(2) To render advice on its own initiative to the Central Government in respect of scientific research and research policy as will advance national interests, particularly during the present emergency
(3) To locate and spell out problems requiring immediate as well as those requiring long-term solutions
(4) To co-ordinate research with a view to getting to work with the problems requiring immediate solution and otherwise to direct research in a purposeful way so as to bring maximum benefit in the shortest time possible.
(5) To assess the research potential, individual as well as groupwise and by disciplines, in Government Research Departments, National Laboratories, Industrial Research Establishments and Universities; locate research personnel of outstanding merit; and, on the basis of information so available, farm out problems of research to individuals and teams of workers so that many lines of investigation can be followed simultaneously towards a co-operative result in the shortest possible time.
(6) To bring on its own initiative to the notice of scientists engaged in research subjects of investigation in their specialized fields, which are likely to be of potential value to the nation in the present emergency
(7) To undertake such other responsiblities as may be assigned by the Government

The National Institute of Sciences, being an independent entity dealing with both pure and applied research, could provide direction for this Advisory Body The personnel could be drawn from the Fellows of the Institute and such other Engineers and Scientists outside the Institute who can effectively implement the programme of research on a highly co-ordinated basis I would lay particular emphasis on the inclusion of Engineers with wide knowledge and experience in innovation, construction and production in this Advisory Body as without intimate inter-play of technology and science, all efforts of pure research will fail in their immediate purpose of helping the defence effort and possibly indefinitely delay the achievement of long-term objectives.

In conclusion, I sincerely hope that the National Institute of Sciences will soon get statutory recognition, which is its due, through an Act of Parliament.

Dr Homi Jehangir Bhabha, FNA*

(Elected to the Fellowship, 1941; President 1963-64)

Dr H J Bhabha was born on October 30, 1909 at Bombay. He received his PhD degree from University of Cambridge in 1935. He was the Professor of Physics at Indian Institute of Science, Bangalore; Director, Tata Institute of Fundamental Research; Chairman, Scientific Advisory Committee to the Cabinet, Govt Electronics Committee and Atomic Energy Commission and the Secretary to the Govt of India in the Department of Atomic Energy. Dr Bhabha was the President of International Union of Pure and Applied Physics and Member, IAEA Scientific Advisory Committee. He was a Fellow, the Royal Society, London (1941); Honorary Fellow, the Royal Society of Edinburgh (1957) and American Academy of Arts and Sciences (1959), Foreign Associate of the National Academy of Sciences (US) He was the recipient of honorary doctoral degrees in Science from Patna, Lucknow, Banaras, Agra, Perth, Allahabad, Cambridge, London and Padova Universities. He was awarded Padma Bhushan in 1954 by the Government of India.

Dr Bhabha will always be known for his work in theoretical high energy physics. He calculated the cross-section of electron positron scattering (Bhabha scattering). He put forward the theory of cosmic ray showers by cascade production of gamma rays and positive and negative electron pairs. In the 'Vector Meson Theory' of Bhabha, he pointed out that the measured lifetime of a meson in flight is affected by the time dilatation predicted by Einstein's Special Theory of Relativity, and we know today that this measurement is the most direct demonstration of that phenomenon. He was the brain behind the growth of the atomic energy establishments in India.

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*died in 1966.

REMARKS DURING CONSIDERATION OF ANNUAL REPORT

H J Bhabha

(delivered at New Delhi on October 1963)

This is the first occasion on which I have the honour to address you as the President of this Institute I am grateful to you all for conferring this honour upon me, and I shall do my best to promote the cause of science in India and the genuine interests of this Institute I shall speak on only some matters referred to in the Annual Report and also of important events in the world of which we must, as scientists, take note

I am sure you would all wish me to refer on this occasion to the very great loss which the world of science has suffered in the death of Professor Niels Bohr, one of the greatest scientists of our age and one whose name will be remembered as one of the greatest in the history of science His three great papers, published in 1913 laid the foundations of atomic theory. It is well known that atomic theory has produced one of the greatest revolutions in human thought since relativity, and it is a measure of the greatness of the scientific age we have the privilege to live in that two of the most revolutionary advances in human thought and in understanding the world we live in should have been made within our life time As a result of his human qualities and character, Professor Bohr continued to play a unique role among scientists right up to the end. His death is a great loss to the world of science, but for those who knew him personally the loss is irreparable.

Among the events in the world of which we must take notice as scientists, perhaps the most important is the Treaty negotiated between the Union of Soviet Socialist Republics, United Kingdom and the United States of America, banning the test of atomic weapons in the sea, in the atmosphere and in outer space, a Treaty which has now been signed by no less than 90 States. India was among the first to sign this Treaty outside the three negotiating parties, and this is but one more proof of the determination of this country, under the leadership of the Prime Minister, Shri Jawaharlal Nehru, to use atomic energy only for the benefit of mankind and not for "evil purposes". The signing of this Treaty was a limited, but an important step forward, which will certainly lead to an improvement of the international atmosphere This step however must be followed by another, and then another, leading ultimately to total disarmament under international control Such a development, which we as scientists should all strive to promote, will release vast resources for human betterment which are at present being squandered on military preparations and armaments If only a small fraction of the money so released is devoted to science, there will be a development of science in the world which will overshadow all that is being done at present It will be possible to abolish from this world hunger and poverty and to provide to each human being in ample measure the material necessities of life, such as food and shelter, as also education and proper medical care and the opportunities for a full development of his personality and abilities.

Another subject which is of great importance for the world as a whole, but which is of the greatest importance for the underdeveloped countries, is the growth of human population This makes our problem of raising the standard of living, difficult as it is for many hundred million people, even more difficult than it would be otherwise. Before the last census, the birth rate in India was given as 3·9% and the death rate 2 6%, resulting in a net growth rate for the population of 1 3%.

The last census showed that the net growth rate has now gone up to just over 2%. This is directly the result of the application of science and technology to improve medical attention and health, which has increased the chances of survival What we need is a commensurate application of modern science and technology to the problems of family planning, even on the basis of presently known methods While a good deal has been done by our Government and through private initiative, the total effort is far below what it should be, as the increase in the rate of the growth of the population clearly shows. We need a much greater effort in this direction, and it is the duty of the Fellows of this Institute, and indeed of all scientists, to draw the attention of the Government, and to educate the public in appreciating, the seriousness and the implications of this problem. The measures required in India to make an effective impact on this problem are of such enormous proportions that a slight improvement or simplification in the present methods or the discovery of new ones would have very far reaching results on the efforts and the resources required. This is a field therefore in which we should urge the Government to spend much larger funds for research, and the Government might well consider assisting research in this field in other countries also purely in our own interest.

One of the points that will come up for consideration this year is the proposal that an Act should be passed regarding the National Institute. I feel it my duty to exchange my thoughts frankly with the Fellows of the Institute on this occasion, as it is only thus that progress can be made. The National Institute was founded in 1935. In the years from 1943 to 1945 the question of the recognition of the Institute by the Government of India as the representative body of scientists was taken up, and negotiations were held in Delhi on behalf of the Institute by Professors J C Ghosh, P N Saha, S S Bhatnagar, D N Wadia and myself with the then Department of Education, Health and Land. As a result the Government decided in 1945 to recognise the National Institute as *the premier society representing all branches of science in India* This alone should have given the National Institute a great impetus, but we find twenty years after this recognition that the Institute has not earned for itself the position in the life of the country which it should have

At the time in 1943 when we approached Government for recognition, there were several eminent scientists who felt that the National Institute did not satisfy the criteria for such recognition. While I agreed with those scientists that the Fellowship and the performance of the National Institute at the time was not such as to merit such recognition, I was persuaded by my late friend and colleague, Dr S S Bhatnagar, that the membership and work of the Institute could be improved over the years and decided, therefore, that it should be given a chance. While it is said that the National Institute has in its Fellowship some of the best scientists in India, the fact remains that there is a very considerable number of very good young scientists who are not among its Fellows Moreover, I have watched the elections carefully over a period of years and find that often in the same subject it is not the best and most outstanding research worker who is elected, but one who may be senior or one who may have more influence in view of the administrative position he holds. This is not the way a great academic body and a great academic tradition can be built up. I do not attribute this circumstance to any malafides, but as a well known Tamil proverb says *Only the learned can recognise the learned*, and it is only the outstanding workers in the subject who can discern who is the most outstanding worker, and who not quite so outstanding. Therefore, unless the Fellowship itself is at the highest level, which can be attained in India today, or the Fellows are willing to leave the selection of future Fellows to a small group having an established and world-wide reputation, I can see no chances of the level of the

Fellowship improving. Science is still weak in India compared to its development in the industrially advanced countries, and if we are to pitch the level of our Fellowship at a level not greatly below that of the Royal Society or the Academies or Sciences of the United States of America and Union of Soviet Socialist Republics, then the total number of our Fellows would necessarily have to be a small fraction of our total present Fellowship.

It is for this reason that it was proposed that the Institute might have a second and more restricted category of members, called 'Academician', who would be selected only on this basis, and which would necessarily have to be entrusted with determining the future election of Fellows and all important matters connected with the running of the National Institute. The structure so envisaged will be on the lines of that of a number of academies, as for example, the Union of Soviet Socialist Republics Academy of Sciences, which has Academicians and Corresponding Members. Under this proposal the bulk of the present Fellowship would automatically take the place of the Corresponding Members This would indeed be a great act of self denial on their part, but a decision which they would have to make, if the move to give the National Institute the statutory recognition which some want is to be widely supported I see from the draft which has now emerged, that this principle has not found wide acceptance, and I doubt therefore whether the move to get statutory recognition will receive sufficient support in all quarters. You will permit me to express my own views frankly. In the present state of the National Institute and without some of the drastic changes which have been mentioned, I do not think that it qualifies for the type of recognition that is sought. I do not even think that such recognition would be in the best interests of science in the country. On the other hand, the lack of such statutory recognition does *not* come in the way of the genuine work of the Institute. If the Institute strives to raise its academic standards and achieves for itself a place in Indian science which is widely acclaimed by those who should know and judge, the statutory recognition will automatically fall into its lap. I would therefore urge on members that they should devote their energies and attention to genuinely scientific matters and not let the question of statutory recognition obsess them

Talking now of wider field, I feel that we in India are apt to believe that good scientific institutions can be established by Government decree or order A scientific institution, be it a laboratory or an academy, has to be grown with great care like a tree Its growth in terms of quality and achievement can only be accelerated to a very limited extent. This is a field in which a large number of mediocre or second rate workers cannot make up for a few outstanding ones, and the few outstanding ones always take at least 10 to 15 years to grow Too many of our National Laboratories have been established by deciding upon the field in which it was desired to work and by drawing up an organisational chart on the pattern of some corresponding large laboratory abroad It was then assumed, naively, that the posts in the chart could be filled by advertisement, forgetting that workers of the appropriate and high level either do not exist in India, or can only be obtained at the sacrifice of some other institution, which thus becomes weaker for it. Our universities, weak as they always were, have been further weakened in this manner.

I would urge upon the Members of the Institute to think carefully upon the problems of developing science in India and of developing the National Institute. Both these tasks require all our joint energies and devoted work, and results will come slowly but surely, if the problem is approached in this way.

Professor Vasant Ramji Khanolkar, FNA[1]

(Elected to the Fellowship 1960; President, 1965-66)

Professor V R Khanolkar was born on April 13, 1895 He obtained MD in Pathology from University of London in 1923 He was the Professor of Pathology, Grant Medical College (1924-25) and later SGS Medical College and KEM Hospital (1925-40) in Bombay; Director, Indian Cancer Research Centre and Honorary Director of Laboratories, Tata Memorial Hospital, Bombay; Vice-Chancellor, University of Bombay; National Research Professor in Medicine (since 1963). He was the Honorary Fellow, Royal College of Physicians of Edinburgh; Member, Pathological Society (UK); President, Society of Biological Chemists; Honorary Fellow, American Association of Cancer Research, President, Indian Association of Pathologists and International Union against Cancer, Honorary Fellow, New York Academy of Science and Australian Cancer Society, Fellow, International Academy of Pathology, Academy of Medical Science (USSR); President, Indian Society for Study of Reproduction; Chairman, Biological and Medical Advisory Committee of Govt. of India He was associated with several committees of CSIR, WHO and Planning Commission He was the recipient of Padma Bhushan (1955), LLD degree *(h c)* of Melbourne University (1960) and DMS degree *(h c)* of Perugia University (1961)

Professor Khanolkar had contributed greatly to the knowledge of Human Pathology.

THE STORY OF THE INDIAN CANCER RESEARCH CENTRE, PAREL, BOMBAY

V R KHANOLKAR

(delivered at New Delhi, 1966)

Since the days of Sir Lewis Fermor, the first President of the National Institute of Sciences of India, it is the usual practice of the President to talk on the specialized branch of science he has developed. I should, however, like to make a slight departure from tradition Rather than talk to you about one problem, I would like to narrate briefly the development of the Indian Cancer Research Centre and then describe some of the work done there in the newer disciplines of science under my guidance

The Indian Cancer Research Centre was inaugurated in December 1952 Since then a number of periodical progress reports have been compiled detailing all its scientific activities. It is, however, fitting today that I should tell you about the first 10 years of life and work at the Centre It had always been my idea that the Department of Pathology, Tata Memorial Hospital, with which I was closely associated since its inception, should form the nucleus for the establishment of the Centre for advanced basic research on cancer In 1952 this became possible with the co-operation of the Government of India and Sir Dorabji Tata Trust, and the Indian Cancer Research Centre took the present shape

Cancer research involves an interlocking of several disciplines in science and medicine Accordingly the following different departments and sections have slowly developed during this decade: (1) Applied Biology, (2) Experimental Embryology, (3) Human Variation and Statistics, (4) Endocrinology, (5) Biochemistry, (6) Enzyme Chemistry, (7) Biophysics and (8) Microbiology (including Electron Microscopy). All the above departments and sections are looked after by well-trained experienced scientists The Centre is a constituent recognized institute of the University of Bombay and is also approved by the University of Poona for post-graduate research As such some of the best students are attracted to the laboratories for training in advanced research techniques and post-graduate degrees of Master of Science and Doctor of Philosophy At present the total research, technical and maintenance staff is about 250, including those employed on units and schemes sponsored by other organizations such as the Indian Council of Medical Research, the Council of Scientific and Industrial Research, etc.

The general programme of work at the Indian Cancer Research Centre is best described under three main headings experimental and clinical studies in cancer, leprosy and physiology of reproduction Another important activity of the Centre consists of starting new disciplines at the post-graduate level and improving the teaching of post-graduate students for MSc and PhD degrees

Cancer is being studied from different aspects—its causation, mode of occurrence, biological behaviour within the host system and therapy. Different disciplines and techniques of Biology, Biochemistry and Biophysics are used, as is necessary in the investigation of malignancy in all its multiple manifestations Biological research consists of study at two levels systemically in laboratory animals (mice, rats and hamsters), and at the cellular level in tissue culture. In the animal experiments on the mechanism of Carcinogenesis, two main problems under investigation are (1) spontaneous and (2) chemically induced cancer of the breast and skin In breast cancer the main attempt is to study the mode of action of intrinsic and extrinsic factors in the production of neoplasia and thereby to elucidate the steps in the process of carcinogenesis, *viz* initiation, promotion, development and progression of tumours Mammary cancer in mice has been induced mainly by potent carcinogens such as 20-MCA and 1, 2, 5, 6-dibenzanthracene The skin carcinogenesis studies may be divided in three parts In the first, chemicals are being tested for their carcinogenicity to correlate their chemical constitution with the cancer-producing activity of the substance. The hypotheses put forward by theoretical chemists for carcinogenicity of substances due to the presence of 'K' and 'L' regions are being tested in these experiments. The second part of the experiment is for testing substances for their suspected etiological role in clinical cancer, like tobacco in relation to oral cancer, chinar leaves in relation to 'kangri cancer', iron complexes in relation to induced sarcomas, and edible oils for their mutagenic effect. The carcinogens are administered at different sites· skin, subcutis and target organs like mammary glands and ovaries The role of steroid hormones in the mechanism of experimental skin cancer is also being investigated in detail in rats and mice Varied techniques of optical histology, histochemistry and electron microscopy are used.

Experiments in embryology are being conducted by painting virgin ovaries and studying progenies of treated mice for many generations A series of carcinogens is under investigation for their mutagenic action in these experiments, details of which have been recently published. Another problem specific to India is the condition known as Submucous Fibrosis of the Palate observed in many ear, nose and throat clinics. It is suspected that some irritant food additives or certain spices like chillies have some bearing on this condition. Clinical and experimental studies are in progress to investigate the etiology and pathogenesis of Submucous Fibrosis of the Palate.

In cell biology many tissue culture techniques have been standardized and developed. The tissue culture work is mainly divided in two parts One is the continuous cultivation of stock of cell lines (*a*) imported commercial cell lines and (*b*) those developed at the Tissue Culture laboratories of the Centre, particularly from human and mouse sarcoma These cells are supplied to the Virus Research laboratories in India for cultivation of viruses and are used in the Centre's laboratories for various experiments like tissue interactions, nutrition of cancer cells, studies on cell transformation in continuous cultivation, etc Various cytological and cytochemical studies are simultaneously in progress on all the 'ICRC' cell lines maintained in stock An aspect of cell biology developed since the inception of the institute concerns subcellular organization and the fine structure of cancer cells in relation to their altered metabolism and biological behaviour. Some of the varied problems studied are differential metastasis in skin cancer, alteration in connective tissue fibroblasts in hormonal stress and neoplasia, nucleic acid metabolism in malignancy, submicroscopic cytological response to cancer chemotherapeutics and so on

Genetic and epidemiological studies on cancer also form part of biological investigation of this disease process. Some of the problems specific to India are studied, such as:

(*a*) incidence of cancer and survey of habits in relation to cancer etiology,
(*b*) human genetics and cancer (blood group studies, etc),
(*c*) hereditary anaemias

Oral cancer forms a major part of all malignant lesions occurring in this country. Large-scale population surveys were carried out to evaluate the role of habits and other environmental factors. Statistical data are carefully collected on the high incidence of cancer of this site compiled and analysed every year. Another problem in progress in human genetics is blood group frequencies in relation to cancer.

Endocrine disorders observed in some endogamous groups in India are also under investigation The important problems in this category are intersexuality and chromosomal investigation.

Biochemical research on cancer can be described from three viewpoints: (1) the chemistry of substances suspected to be carcinogens, (2) the basic enzymic aberrations specific to malignancy and (3) chemotherapy. Substances implicated in the etiology of cancers of different sites, such as tobacco in relation to oral cancer, chinar in skin cancer and smegma in cancer of the penis and cervix, are being chemically investigated Detailed fractionation studies are in progress with a view to any possible isolation of specific carcinogenic fractions from them. Some interesting observations are available on the B-glucorunidase activity in oral cancer patients Some of the basic studies are on the metabolism of the Sulphur-isoesters of polycyclic hydrocarbons that are being tested for their carcinogenicity. Enzyme studies have been carried out on Folic Acid Metabolism and Liver Tumours and the role of Enzymes in the action of Venom. Other important problems under investigation are studies on Mitochondrial Enzymes in Tumours and Metabolism of the Antileukemic drug, Aminopterin.

The chemotherapeutic studies on the problem of cancer were started very recently. The Centre has been able to develop a new line of work on antimetabolites against the intermediates of Hexose-Mono-Phosphate (HMP) pathway. Three antimetabolites of 6-Phosphogluconic Acid: TDA, DICETOL and TDGA, tested for their growth-inhibiting activities, have given significantly promising results in experiments. The tumour material used for these studies was mostly Yoshida Sarcoma (Ascites) and a solid Mouse Fibrosarcoma developed at the Centre. Clinical trials of these drugs on some advanced and incurable human cancer cases are in progress.

Chemotherapeutic studies with indigenous plants have also been undertaken. Preliminary experiments on a Himalayan plant, *Hippophae salicifolia*, locally known in the Punjab as Kalabis, have shown encouraging results in regression of transplanted Yoshida sarcoma in animals

Biophysical studies in cancer include

(*a*) electron microscopy of Bidi and Cigarette Smoke in relation to cancer,
(*b*) a study of the effects of ionizing radiations on Amino Acids and Nucleic Acids,
(*c*) studies on the complexes of DNA and RNA with the dye Acridine Orange

Biophysics is a new discipline started at the Centre and has been introduced in the Bombay University curriculum at the MSc and PhD levels

Another new discipline started at the Centre and introduced at the University at the MSc and PhD levels is that of Applied Biology. The basic disciplines of biology are considerably developed in recent years and several biological techniques are used in the investigation of medical and allied problems It was felt, therefore, that there was enough scope for having a separate discipline of Applied Biology in which useful research work could be done The Centre was the first institute to introduce the subject and has been recognized by the University of Bombay in the subject. There is much enthusiasm among young people for these two new disciplines

Special mention must be made of the interesting biological material which the Centre has been able to develop during the last few years. The Centre has been using about a dozen imported strains of inbred mice for cancer investigations It has also bred the following three strains of its own with uniquely useful genetic properties:

(1) An I.C.R C. line of albino mouse.
(2) An inbred line of (LP) mouse.
(3) A hybrid of Paris XVII and C-57 (Bl) strains.

The ICRC mouse is a large-size mouse

weighing about 50-60 gm at six months, as compared to 25-30 gm which is the weight of inbred American or European strains of mice. This breed has been found to be highly susceptible to spontaneous breast cancer. The inbred line of (LP) mouse was developed from a small stock imported from Paris. It is resistant to spontaneous breast cancer but is highly susceptible to chemical induction of mammary cancer. It differs characteristically from the ICRC mouse in its endocrine system and is specially useful for the study of chemical carcinogens. The third breed of mice is the hybrid of one Paris stock crossed with C-57 (Black). Both the strains are breast cancer resistant and their crossed breed also has a very low incidence of spontaneous breast cancer. This strain is particularly useful for studies on skin carcinogenesis.

Besides these three inbred lines of mice, some standard mouse tumours—mammary carcinomas and induced sarcomas—have been developed and kept in serial transplantation for over five to seven years now and used as standard experimental material. Recently it has been possible to develop an ascites tumour from one of the solid mouse tumours, which could also be used in the place of Ehrlich ascites tumour. There are several strains of ICRC cell lines maintained in continuous cultivation over five years. Very few laboratories in the world are maintaining sarcoma cells in continuous cultivation. Therefore, human and mouse connective tissue cell strains, *e.g.* Human Lipogenic Sarcoma (HLS[2]), Human Fibrosarcoma (HFS[8]), Mouse Fibrosarcoma (MFS[9]) and Mouse Skeletal Muscle (MSKM) and their sub-lines have been specially developed.

One other type of biological material developed at the Centre is an acid-fast micro-organism isolated from lepromatus leprosy designated as the 'ICRC bacillus'. It has been possible to isolate the organism successfully from six different leprosy patients and the extensive studies carried out *in vitro* have shown several points of its close similarity with *M. leprae*. This is another useful bacterial culture which several laboratories abroad (Europe, the USA and Australia) have taken from here with a view to studying the different metabolic and growth aspects of the bacillus.

The habits and usages of Indian people seem to favour the causation of cancer at certain selective sites in the body. Similarly there seems to be a preference for varied types of endocrine disfunction among different endogamous Indian communities.

Abnormal growth of hair, or hirsutism, for which no definite cause can be found, is seen mainly in two endogamous communities in Bombay, namely, Sindhis and Parsis. Such growth of hair usually starts after the onset of puberty and continues during active reproductive life. There is very often a suggestive family history. The defect involved here appears to be of a minor degree, because these cases usually do not have any virilization and have normal menstrual function and procreative ability no less than in other members of the family without abnormal patterns of hair growth. No critical history as to the origin and evolution of the first group, *viz.* Sindhis, is available, except that the large bulk of their population has only recently migrated from West Pakistan to the West Coast of Gujarat and to Bombay City. On the other hand, the Parsis are the descendants of the people who came from Iran (Persia) after the fall of the Zoroastrian Empire at the beginning of the eighth century. Iranians have continued to migrate during the subsequent centuries to India to a limited extent and the children of Parsi fathers by alien mothers were also admitted to the Parsi fold. The total population of Parsis is 132,000 (1961 census) and a large majority of them live in Bombay. A point of equal interest is that Parsis are permitted consanguineous marriages, the incidence of marriages amongst first cousins being as high as 15 per cent, perhaps the highest in civilized population. It is, therefore, reasonable to assume that physiological peculiarities would be more common in Parsis than in Sindhis.

Adrenocortical and ovarian functions have been investigated by a series of tests in a number of cases in these two groups. Some of these cases, having normal adrenocortical and ovarian function on exploratory laparotomy in the second half of the menstrual cycle, revealed the Stein-Leventhal type of ovaries and fresh *corpora lutea*. The fluid collected from the microcystic ovaries of these patients has shown a high amount of Zimmermann positive chromogen in the ketonic fraction, as compared to that in the control group having similar morphological changes in the ovaries but having no hirsutism. The material when biologically tested for androgenicity did not reveal any activity and appears to have a structure similar to the compound Δ^4 Androstene 19-OH-3, 17-dione It has, therefore, been postulated that in these cases there is a partial enzymatic block in the conversion of this compound to estrone, with the result that precursors like Δ^4 Androstene + dione and/or testosterone may circulate in the body and bring about hirsutism In other words, it is probable that the hirsutism in these cases is due to the quantitative difference in the androgen and oestrogen production in the ovary Experiments with labelled steroid compounds to find out the turnover ratio of androgen/oestrogen in normal and in these ovaries have, therefore, been planned.

These and many other conditions are some of the clinical materials of specific interest for studies on geographical pathology that is not available on a large scale in other parts of the world An attempt has, therefore, been made to develop extensive investigations on some of these clinical problems To dream is given to many, but to have a vast vision and translate it into actual reality by one's own efforts is the privilege of a fortunate few. Most of us who are here today have spent many years in the pursuit of science— in its varied disciplines You will all agree that never before has there been such basic integrated approach to the problem of the origin and maintenance of life Our young scientists today are achieving goals that all of us have tried to work for. Many laboratories in the country with their complement of well-trained dedicated workers stand comparison with research institutions in more developed lands That is a matter of continuing pride We have tried to impart some of the enthusiasm for learning and the spirit of enquiry that Claude Bernard has described as the natural prerequisite of a scientist to our younger workers They, I feel, have learnt the lessons well and it is my dearest wish that the flame of knowledge be shielded carefully by them and passed on further to future generations

HABITS AND CUSTOMS AS CAUSATIVE AGENTS OF CANCER

V R KHANOLKAR

(delivered at Hyderabad, 1967)

Cancer is a world problem It has been known to occur in all races of man in which it has been investigated Since the inception of the Tata Memorial Hospital, we have had much experience with the occurrence of this dreadful disease An early and consistent observation was that cancers in some regions of the body are encountered more frequently in some races and communities than in others. Thus, for instance, cancer of the oropharynx is our main health problem in India More than half the cancers in Japan are gastric cancers and skin cancer, which do not occur so commonly in the pigmented peoples, is seen often in the white Australians. An analysis of the first 10,000 cases of the Tata Memorial Hospital convinced us of two facts (1) that the high incidence of cancers of certain sites could lie in the habits of the people and (2) that significantly large population groups had to be surveyed to state emphatically such a correlation between a habit peculiar to a people and the high incidence of a given cancer. This is the topic I wish to digress upon a little today—and outline for you in brief the laborious task that has engaged us for many years—to prove that habits, customs and usages can serve as causal agents for cancer

Bucco-pharyngeal Cancer

In most parts of India and Ceylon, the number of persons suffering from cancer of the mouth and oropharynx far exceeds those afflicted by cancer of any other part of the body. This is particularly striking in the case of men In a study of 2,000 consecutive cancer patients in Bombay during a period of 11 months, almost half (877) presented cancer of the mouth and the adjacent portion of the pharynx The distribution of some of the principal sites in this region of the upper alimentary tract was as shown below:

Site	Percentage of bucco-pharyngeal cancer
Base of the tongue	25
Hypopharynx	21
Buccal Mucosa	13
Tonsil	13

It has been observed that there is a peculiar localization of bucco-pharyngeal cancer in different geographical regions of India, and also in different communities in the same locality.

Cancer of the lower lip (Khaini cancer) Cancer in this form is seen frequently in Bombay (Khanolkar and Suryabai 1945), but in Bihar and the adjacent areas of Uttar Pradesh it is found to be the most common variety of malignant diseases in the mouth

Place	Oral cancer	Lip cancer with alveolus
Bombay 1941-45	2,326	115 (4 91)
Patna, Bihar 1944-46	1,156	661 (57 11)

The figures in parentheses represent percentages of lip cancer relative to total oral cancer.

This remarkably high incidence is associated with the habit, particularly in men, of sucking, slowly, a mixture of tobacco and lime The habit is common in the poorer people who rub with the right thumb a powder of dried tobacco and slaked lime in the plam of the left hand until the desired mixture is obtained. This mixture (*khaini*) is then deposited in small amounts and at frequent intervals, during the day, in the lower gingivo-labial groove and gradually swallowed after dilution with saliva.

Cancer of the mucous lining of the cheek. Cancer of the mucous lining and the adjacent gingival groove overshadows all other types of oral cancer in the south-western coastal regions of India and Ceylon. The relative incidence decreases from south to north reaching a maximum in Ceylon and Travancore.

This type of cancer is believed to follow the habit of betel leaf and betelnut chewing, but it is doubtful whether the usual constituents of betel (*pan*) play any role in its connection In Indonesia, cancer of the cheek is extremely rare, although the Javanese, particularly in rural areas, chew betel leaf and sliced betel nut continuously. Balendra (1946) noticed that of the 246 patients addicted to this habit and observed by him at the Dental Institute, Colombo, during the previous 20 years, none developed oral cancer after they had submitted themselves to adequate dental treatment and followed simple rules of oral hygiene, even though they continued the habit of chain betel chewing

A survey of 10,000 men over the age of 30 years to determine their tobacco chewing and smoking habits, with or without betel leaf and nut, and the influence of these habits on the development of pre-cancerous changes in the mouth has provided some interesting information It appears that betel chewing, far from causing cheek cancer, probably inhibits its development

Chewing habit	Smokers		Non-smokers	
	Number	With oral* signs	Number	With oral* signs
Tobacco only	112	52 (48 2)	1,148	454 (39 7)
Tobacco with betel	990	186 (18 8)	2,352	300 (12 8)
Non-addicts	3,777	1,165 (31 0)	1,617	287 (14 0)

*Oral signs refer to pre-cancerous conditions
The figures in parentheses represent percentages

In Bombay city, cheek cancer is seen more commonly in Deccani Hindus, who work mainly as gardeners, millhands, stevedores and policemen Their habit of chewing tobacco, with or without betel, and of keeping the cud in the cheek for several hours is very common Where the rules of work prevent smoking while on duty, as in the case of policemen, it is common practice to chew tobacco. The association of this habit with the production of cancer is probably dependent on other ancillary factors such as poor oral hygiene, malnutrition and the lack of adequate vitamin B complex in the diet (Waravdekar, Mangaonkar and Khanolkar 1950). It seems likely that the variety of tobacco, the soil in which it is grown and the method of its curing determine largely the changes in the oral mucosa Thus the people of Ceylon chew mainly the Jaffna tobacco; the people of Travancore chew the Jaffna and Menapalayan (Vaddakan) variety, whereas in Bombay the Neepani variety is commonly used

Cancer of the palate (Chutta cancer) In the mid-eastern coastal regions of India (Andhra State) cancer of the hard palate appears to be fairly common

This type of cancer is assocaited with the habit of the reverse smoking (*adda poga*) of a cigar (*chutta*) with the burning end inside the mouth The high incidence of palate cancer in Andhra is probably associated with an exposure to probable carcinogenic substances from the burning tobacco, and the heat generated in the vicinity of the live end of the *chutta* or cigarette.

Cancer of the base of the tongue and tonsil: Cancer of this type is more than twice as common in Gujarati Hindus as in the Deccani Hindus in Bombay.

The Gujarati Hindus are particularly addicted to smoking local cigarettes (*bidi*) made by rolling tobacco flakes in a dried leaf of a variety of *Bauhinia* or *Diospyros.* A study (Sanghvi, Rao and Khanolkar 1955) of 1,460 consecutive patients with oral cancer who attended the Tata Memorial Hospital, Bombay, during 1952-54 is suggestive. It appears that cancer of the base of the tongue and hypopharynx is associated with the combined habit of smoking *bidis* and chewing tobacco. The marked preponderance of this type of cancer is shown below

Cancer of the Base of the Tongue and Tonsil in Males in three Communities — Tata Memorial Hospital Bombay, 1941-45

	Oral cancer	Cancer of base of tongue	Cancer of tonsil
Deccani Hindus	418	148 (35·4)	57 (13·6)
Gujarati Hindus	601	354 (58·9)	121 (20·1)
Muslims	440	198 (45·0)	65 (14·8)

The figures in parentheses represent percentages of tongue and tonsil cancer relative to total oral cancer

The total attendance at the hospital of the Deccani Hindus compared to Gujarati Hindus during this period was in the proportion of 3:2. It is seen that cancer of the base of the tongue and tonsil is more frequent in Gujarati Hindus than in Deccani Hindus Cancer of these organs in Bombay Muslims occupies an intermediate position, as most of them are converts from Gujarati or Deccani Hindus and still retain the language and many of the habits of the people from whom they originated

Cancer of the Skin

It has been pointed out that cancer of the exposed parts of the skin (face, ears, hands and so on) is much less frequent in pigmented races than in fairer people living in the same locality (Puente Duany and Fonts Abreu 1948). In Southern India this variety of cancer does not constitute more than 2 per cent of all cancers In the more lightly pigmented people in tropical countries it is more than 10 times as frequent, particularly in persons who are exposed to wind and sun in the performance of their daily work

There are two types of cancer of the unexposed part of the skin which are peculiar to India and which are associated with particular customs

Kangri cancer The people of Kashmir keep warm by carrying outside, and often under their long shirts, an unglazed earthen pot packed with smouldering dry maple (chinar) leaves The earthen pot is covered with a basket of reeds and is either suspended from the neck or held in the hand In men the use of the Kangri leads to a severe erythema of the skin covering the abdomen and the inner surface of the thighs during the early winter months In women the erythema spreads to the pudendal regions and the lower surface of the breasts. With the coming of spring the erythema subsides, except in a small number of people in whom a mild eczema persists for several months Neve (1900) and Neve (1924) observed a prevalence of squamous-cell cancer of the skin of the lower abdomen or the thighs in the people of Kashmir and associated its occurrence with the use of Kangri and the skin burns frequently caused by it It is doubtful whether the presence of these mild burns affords the entire basis for the causation of this cancer and it may be necessary to study the action of probable carcinogenic substances in the smoke of chinar leaves, and the altered competence of epidermal cells subjected to recurrent inflammatory changes every winter.

Dhoti cancer: In most parts of India a piece of cotton cloth is worn to cover the lower part of the body. This cloth, which for men is called the dhoti and for women is called the sari, is tied tightly round the waist with one of the shorter ends carried under the groin and tucked at the back The poorer people are obliged, through economic necessity, to work, sleep and bathe with the dhoti firmly attached to the loins. The method of wearing this garment is followed after many years by patches of depigmentation, glazing of the skin, acanthosis and, occasionally, carcinoma of the skin of the loin or groin

Carcinoma of the Penis

Low incidence in circumcised races · Phimosis and cancer of the penis are almost non-existent in Jews and are relatively rare in Muslims, primarily because circumcision is an essential ritual in these faiths On the other hand in the uncircumcised Hindus and Chinese it is a frequent disease. The incidence is low in most Western countries (1 25 per cent of all malignant tumours in the male), while it rises to about 5 per cent in some central European countries and Spain (Dean 1935, Sauer and Leighton 1944) and to 8 per cent in Vietnam (Joyeux and Nguyen 1950) The relative infrequency of this type of cancer in circumcised persons has often been commented upon and has been reviewed by Kennaway (1947) His conclusions agree with the findings in Bombay, where no such cancer was encountered in the Jews who constitute roughly about 0 5 per cent of the population In the first 10,000 patients examined at the Tata Memorial Hospital there were only 2 instances of this cancer in Muslims as against 86 in Hindus The attendance of the Muslim to Hindu males during the period was roughly 1 : 3.

In assessing the importance of circumcision in the prevention of penis carcinoma, the age at which the operation is practised and the thoroughness with which it is performed must be considered. In the performance of a ritual, considerations other than anatomical play an important part and, even though the age for circumcision may have been prescribed by religious canon, its observance shows considerable latitude in the Muslims In many parts of India the ritual is usually performed before the age of 6 years In Indonesia the usual age for circumcision is between 8 and 14 years and in a large number of children it is performed by the indigenous medicine man, Dukun Kouwenaar (1933) has referred to the existence of cancer of the penis in circumcised Javanese and its greater frequency in the Chinese who have settled in Indonesia The disease was frequently seen in the Indo-Chinese in North Vietnam

Cancer of the Breast

Cancer of the breast is not seen as frequently by us in India as in most of the Western countries For instance, at the Tata Memorial Hospital it accounted for 7 4 per cent of all cancer cases as against 16 2 per cent at the Memorial Hospital in New York and 16 6 per cent at the London County Hospitals However, cancer of the breast appears to be the second commonest type of cancer in Indian women In an analysis of the first 10,000 cases at the Tata Memorial Hospital there were 655 women with cancer of the cervix uteri and 428 with cancer of the breast A careful study of the distribution of this type of cancer according to communities revealed an interesting fact that it was much commoner in Parsi women than in the different groups of Hindu women In Bombay city there are roughly 30 Hindus to 1 Parsi The frequency of cancer of the breast, however, as observed by us was approximately 3 in Hindus to 1 in Parsis in the patients attending our hospital In other words, 10 times more cancer of the breast was seen in Parsis than could be expected on a population basis of the city. It would be further seen that during the 5 years 1941-45 the frequency of breast cancer in Parsi women was 49·2 per cent of all cancers and only 15·8 per cent in Hindu women In the case of Muslim and Christian women the frequency was in between these two figures and represented 23·6 per cent and 27·8 per cent respectively.

Cancer of the breast occurred at a slightly earlier age in Hindu women than in the Parsis. Thus, for instance, the highest incidence in Hindu women was in the age group of 40-49 and in the Parsi women between 50-59 years As is well known, in Western countries the highest incidence of breast cancer is usually between the ages of 45 and 59. These findings naturally attracted our attention and we have been studying the probable causes for these marked differences in the frequency of breast cancer in the different communities. We believe that the following considerations may play an important role in the production of these differences.

The ancestors of the Parsis migrated to India from Iran many centuries ago. They have tried to carefully maintain the religious observations and inhibitions which they brought with them to India They form a small but well-knit community which tries to keep intact by marrying only between themselves Close inbreeding is very prevalent amongst them and it is believed that this has accentuated the incidence of certain diseases in them. The Parsis have mainly taken to business and are economically a much higher group than the Hindu population.

It was observed that the Parsi women on an average marry 10 years later than the Hindu women. A study of the marital status and the number of children in our breast cancer patients, according to communities, revealed that almost one-third of the Parsi group was unmarried, whereas in the case of Hindu women this proportion was hardly 2 per cent. It was also observed that the proportion of Parsi women with more than 3 children was much smaller than that for the Hindu women. We, therefore, believe that late marriage, fewer children in married women and late and scanty lactation with continued retention of breast secretions contribute towards the production of breast cancer in these women more so than in Hindu women in whom the opposite conditions prevail.

Thus in the last few minutes I have put before you some of our ideas on the provocation of human cancer by man's own environment. Today all research, basic and applied, is geared to the availability of powerful tools I want to emphasize, rather gently no doubt, to a gathering like this, a simple scientific thought first enunciated by John Hunter. That doyen of British surgeons always held that detailed observation and the shifting of facts yielded much knowledge about human disease, its causes and nature Following of these precepts in our investigations over the last few years has, you will all agree with me, yielded a rich harvest indeed.

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Professor Tiruvenkata Rajendra Seshadri, FNA

(*Elected to the Fellowship, 1942, President, 1967-68*)

Professor T R Seshadri was born on February 3, 1900 at Kulitalai in Tiruchi, District of Tamilnadu. He received his PhD degree from University of Manchester. He was the Senior Lecturer and the Head of new Chemistry Department of Andhra University at Waltair, Professor and Head of Chemistry Department, University of Delhi He was a Fellow, the Royal Society, London; the member of the Pharmacy Council of India, Ministry of Health and Governing Body of Indian Council of Medical Research. He was the Chairman of the Chemical Research Council of CSIR, a member of its Governing Body, Chairman of the Executive Council of the RRL, Jammu; Member, the Executive Council of the NCL, Poona, and of the RRL, Hyderabad (all under the CSIR). He was Chairman of several expert committees of Indian Council of Medical Research, Council of Scientific and Industrial Research and the Indian Council of Agricultural Research, the UGC and the Ministry of Education and Scientific Research, the Ministry of Health, Ministry of Agriculture, Ministry of Defence and the Department of Atomic Energy of the Govt of India He was Chairman of Review Committee of the IISc, Bangalore and of the Indian Lac Research Institute, Ranchi. He was a member of the SACC and COST of Govt of India. For sometime, he was a consultant to the UNESCO

Professor Seshadri's major contribution is in the field of chemistry of natural products The isolation and structural elucidation of the flavonoid pigments of Indian plants, coumarins and the related groups of chemicals caught his attention He was involved with the rational utilization of natural resources like medicinal, poisonous, dyestuff, insecticidal and other economically important plants. Professor Seshadri was the pioneer Indian chemist who made an extensive chemical study of the lichens of India and their chemical components, involving degradation and synthesis. Professor Seshadri has propounded biogenetic theories on practically all the groups of compounds which came to his attention

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*died in 1975.

COUMARINS AS NATURAL PRODUCTS, A FIELD OF PERENNIAL INTEREST

T R SESHADRI

(delivered at New Delhi, 1968)

In the progress of the chemistry of natural products during the past century and a half, coumarins have played an important part We have had a large number of occasions to deal with them in the course of our own investigations I propose to deal with some of the more important of these subjects

Early studies

The parent compound of this large group of natural products is a comparatively simple substance and was discovered by Vogel in 1820 He isolated it from tonka beans, seeds of *Dipterix odorata*, a plant found in South America, and called it tonka benzoic acid Actually crystals of the substance could be found inside the cut bean Gerhard and Dumas determined its molecular formula correctly as $C_9H_6O_2$ in 1846 Later in 1868, its constitution was established by its synthesis (Chart 1*a*) by W H Perkin (Sr) In essence this continues to be the method of commercial synthesis but there were great difficulties of obtaining good yields It involved the condensation of salicylic aldehyde with sodium acetate and acetic anhydride and was the first example of the well-known 'Perkin's reaction' Generally it gives poor yields and is temperamental, being markedly influenced by the purity of the reagents and the reaction conditions. The by-products which may become considerable are acetylcoumaric acid and salicylaldehyde triacetate. The addition of catalysts like iodine and zinc chloride has been reported to increase the yield of coumarin. Salicylaldehyde as starting material is also quite costly Improvements have been made in its preparation (Chart 1*b*) from orthocresol and condensation with cyanoacetic acid yielding coumarin-3-carboxylic acid which undergoes decarboxylation to yield coumarin. Coumarin is one of the most important aromatic compounds, and its annual production is very large It is used extensively in perfumery because of its characteristic pleasant odour and to a greater extent for flavouring purposes, e g artificial vanilla compositions Large quantities of coumarin are consumed by the bakery industry to impart a pleasant and palatable vanilla-butter note to cakes and biscuits The beverage industry is another user of coumarin and many soap perfume formulae contain a small percentage of coumarin; it is also added to smoking tobacco in order to impart a pleasing aroma More recently, coumarin is being used in ever-increasing quantities as a neutralizer of disagreeable odours of many industrial products such as rubber and plastic materials, as well as household articles such as curtains and aprons and even in paints and sprays Coumarin also possesses several useful physiological properties, it has antifungal action and controls seed germination and root growth

In the closing years of the last century and the early years of this century, a large amount of work was done on the physical properties and chemical reactivity of the coumarin molecule, and the preparation and reactions of substituted coumarins. Substitutions readily took place in the positions 6, 8 and 3 and many derivatives were obtained The marked stability of the coumarin structure and its properties were considered to indicate that it has an aromatic structure as shown in the following formulae (Chart 2). It satisfies Huckel's rule for aromaticity. In some respects, however, it can be compared to phenyl cinnamate with only one benzene ring.

About the same time, several methods of

synthesis of coumarin and substituted coumarins were studied Besides Perkin's reaction the well-known Pechmann's method and its various modifications were developed and used. Some of the products occurred in nature, e g umbelliferone, aesculetin, daphnetin, limettin and bergapten and some of them were found to be useful as drugs, eg. derivatives of coumarin-3-carboxylic acid A large volume of data was collected about them

The double bond in coumarin is a centre of reactivity; besides inorganic compounds like sodium bisulphite and mercuric chloride, compounds with reactive methylene groups readily add to it, and produce a variety of compounds The reactivity is considerably controlled by substitution in the various positions Another study is the geometrical inversion in the *o*-hydroxy cinnamic acids derived from the coumarins (Chart 3). It is markedly catalysed by

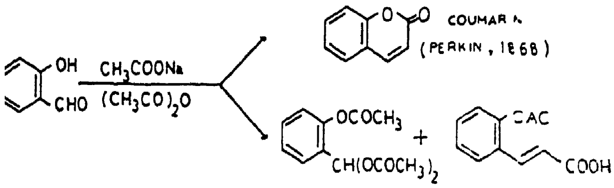


CHART 1*a* Perkin's coumarin synthesis.

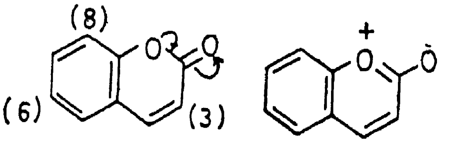


CHART 2 Ordinary and polarized forms of coumarin

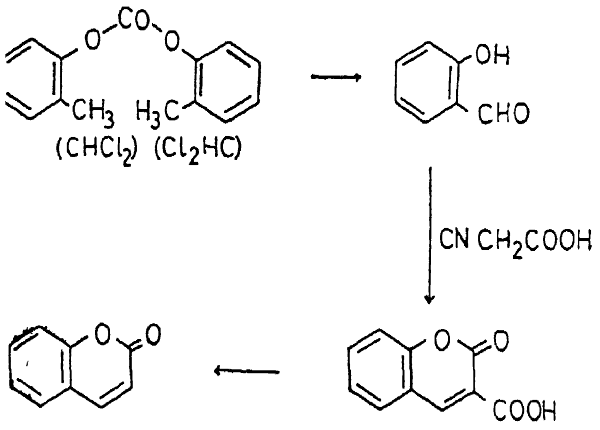


CHART 1*b* Improvements in coumarin synthesis

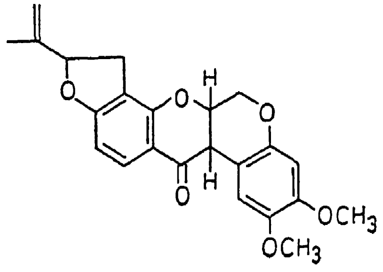


CHART 10 Structure of rotenone.

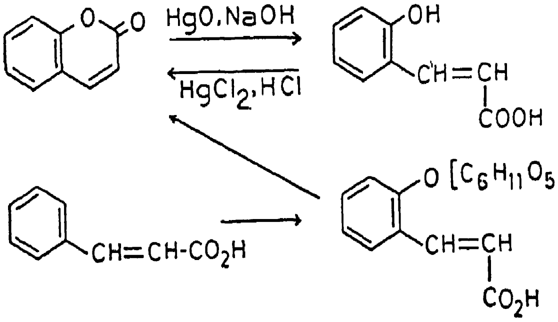


CHART 3. Geometrical inversions and biogenesis of coumarin

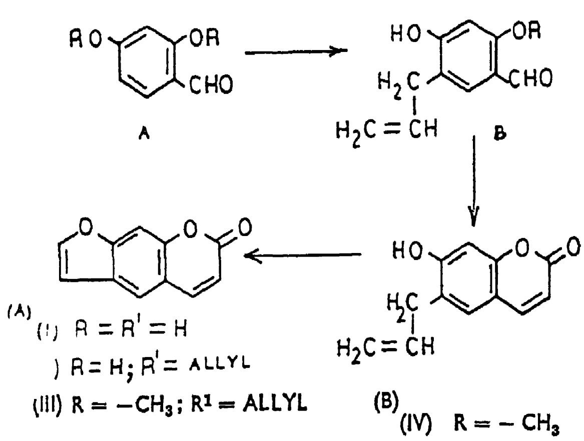


CHART 5. Synthesis of psoralen.

mercury compounds and influenced by light. A typical example is the complete conversion of coumarin into coumaric acid (trans) when shaken with dil. sodium hydroxide and mercuric oxide for ten minutes. The reverse change of coumaric acid or ester into coumarin takes place fast with mercuric chloride in acid medium or when exposed to sunlight. Analogous process of catalysed ring closure from trans acid to coumarin was suggested for its biosynthesis in plants This has been realized in recent years. The origin of coumarin seems to be cinnamic acid which undergoes oxidation and glucoside formation to yield O-glucoside of coumaric acid that has been found to occur in plants By enzyme hydrolysis of the glucoside and ring closure either involving illumination or catalyst, coumarin is produced (Chart 3).

Photodynamic coumarins

During the thirties, active work was done on the chemical components of plant drugs which had been for a long time used for the cure of skin diseases, like psoriasis and leucoderma. The seed of a leguminous plant commonly growing in various parts of India, called *Psoralea corylifolia*, was being used in this way. It was found to contain, as main components, psoralen and isopsoralen (Chart 4*a*) Their constitutions were established as isomeric furanocoumarins Further, the seeds of *Ammi majus*, largely grown in Egypt and also to some extent in Indian gardens as an ornamental plant and used for a similar purpose, were found to contain xanthotoxin, imperatorin and bergapten Later, these compounds were found in a number of other sources also The widespread occurrence of such compounds like bergapten and xanthotoxin explains the frequent incidence of photodermatitis of vegetable origin; for example, celery and parsley cause dermatitis in the hands of people who handle them and this has been traced to the presence of vergapten in them.

The photodynamic property of the above coumarins has been studied in detail in recent years and is found to differ markedly from the activity of hypericin and fagopyrin (Chart 4*b*) which are present in certain plants used as cattle fodder and cause undesirable photosensitiveness to animals. The coumarin group can be used as drugs Therefore effective methods of preparing these compounds from the plant sources have been satisfactorily developed. Special mention may be made of psoralen-isopsoralen mixture from *Psoralea* seeds in India and xanthotoxin and related compounds from *Ammi majus* seeds in Egypt. There were difficulties in their synthesis by the methods known earlier. Most of them were tedious and gave poor yields We have recently described new procedures based on considerations of possible biosynthesis of these compounds in plants Psoralen and xanthotoxin can be made conveniently in less number of steps and in good yields (Chart 5) The main intermediates are C-allyl compounds which are subjected to oxidation and ring closure

Dicoumarol group

A very important discovery was made in 1940 by Link and his co-workers They studied the cause of the haemorrhagic disease of cows that had been fed on spoilt clover The toxic chemical substance was isolated and named dicoumarol Its constitution was given as in Chart 6 (R=H). It had already been synthesized by Anschutz as early as 1909 in the course of his study of the properties of 4-hydroxycoumarin called also as benzotetronic acid. It condensed with formaldehyde to yield dicoumarol. Link *et al* considerably improved the synthesis (Chart 7) It was extraordinary that clover hay which normally contains coumarin had developed the new compound under improper conditions of storage when the clover got spoiled. Its formation was considered to arise as shown in the formulae (Chart 8) and involved a stage of oxidation.

The interesting result is that this toxic compound has turned out to be a very useful drug; it functions as anticoagulant

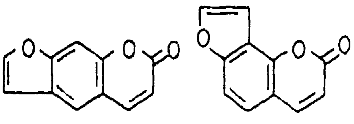
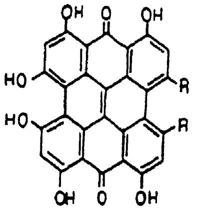


CHART 4a Components of *Psoralea* seed, psoralen and isopsoralen



(I), R = $-CH_3$

(II), R = $-CH_2-(C_6H_{11}ON)$

CHART 4b Hypericin and fagopyrin

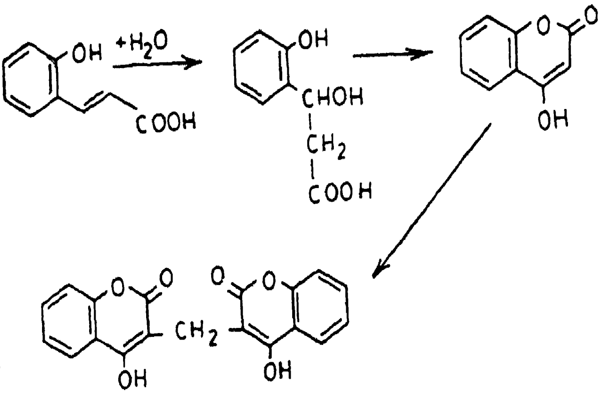
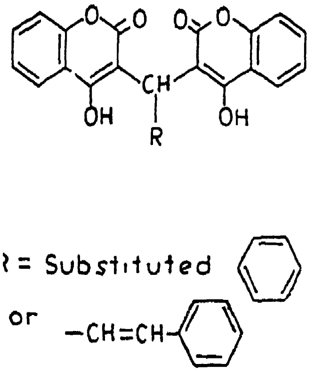
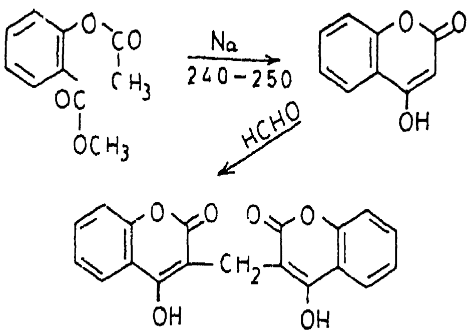


CHART 8 Biogenesis of dicoumarol.



(6)



(7)

CHARTS 6 and 7. 6, dicoumarol and its derivatives, 7. synthesis of dicoumarol.

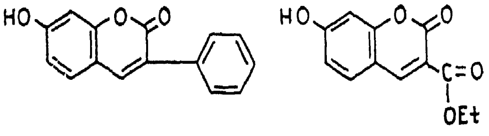


CHART 9 7-hydroxy coumarin (umbelliferone) derivatives

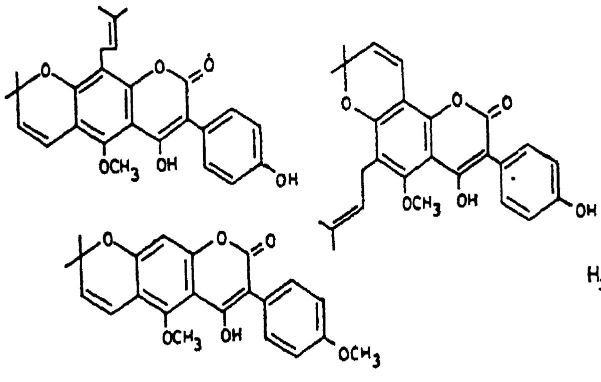


CHART 11 Lonchocarpic acid, scandenin and robustic acid

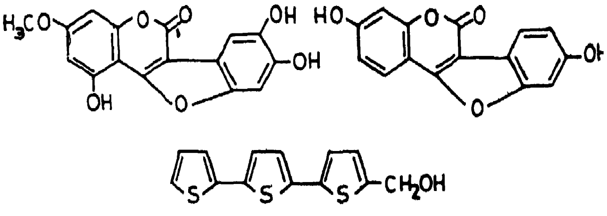


CHART 12 Wedelolactone, coumestrol and terthienyl carbinol

and is thus used. A large amount of research has been done to prepare derivatives with better properties. 'Syntrome' is one such. By a deviation in the synthesis can be prepared a useful rodenticide which goes by the name wharfarin.

In order to learn more about the mode of action of the coumarin anticoagulants from structure-activity correlation studies, we investigated dicoumarol derivatives having a phenyl group on the bridge methylene un-substituted as well as variously substituted The prevailing theories that anticoagulants have anti-vitamin K action and that hemi-ketal formation is a key step in their functioning do not seem to be adequate to explain all observations Though the introduction of a phenyl group on the bridge in dicoumarol considerably brings down the activity, it could be stepped up to varying degrees by introducing various substituents on the phenyl, e g a methoxyl at the 4′-position which seems to produce some other desirable properties also; similar is a styryl derivative obtained by the action of cinnamic aldehyde on 4-hydroxy coumarin (Chart 6)

3-Substituted umbelliferones

Earlier work had shown that several coumarins exhibit considerable fish toxicity, 3-phenyl umbelliferone derivatives were specially good There was an example of picrotoxin that was a fish poison which also possessed antiveratrinic and antiarrythmic activities Based on this analogy coumarins of different types were prepared and tested for antagonizing the veratrine response in the muscle of frogs. The best among these were 7-methoxy-3-phenyl coumarin and 7-methoxy-4-phenyl coumarin, each of which was three times as active as quinine.

Coumarin derivatives have marked fluorescence and some of them give bright fluorescence not only in UV but also in ordinary daylight. Coumarin itself fluoresces in conc. sulphuric acid; umbelliferone is much better. A detailed study of a large number of coumarins was made by us during the last war. The influence of substituent groups and solvents were traced to their effect on the resonance of the molecular structure; the double bond in the pyrone ring is essential for this purpose. A hydroxyl or methoxyl in the 7-position and an electron sink in the 3-position considerably enhance the fluorescence. Among them 3-phenyl and 3-carbethoxy umbelliferone (Chart 9) and their methyl ethers are very powerful They fluoresce in neutral alcoholic solution and even in the solid state Some of these may be useful against sunburn and for radiation protection Experiments have been made by Baker and Haksar incorporating these structures in other compounds for improving chromatographic separation of colourless compounds, 7-methoxy coumarin-3-carboxylic acid is one of the most useful for this purpose

Coumarins of Derris species

During the war years there was great interest in the study of Indian *Derris* species because owing to the occupation of Indonesia and Malaysia by Japanese forces, the supply of *Derris* as a safe and

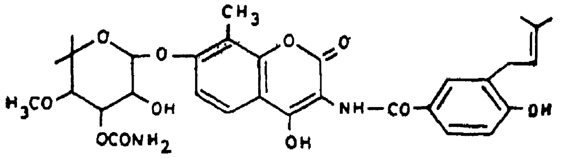


CHART 13 Novobiocin

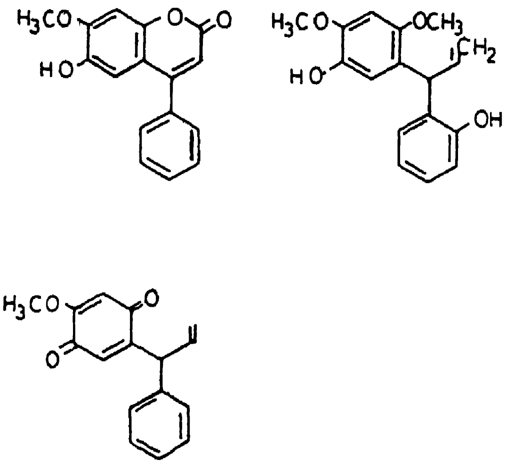


CHART 14. Dalbergin, latifolin and dalbergione

powerful insecticide was cut off. At this time it was well established that rotenone (Chart 10) and closely related rotenoids are the active components of *D. elliptica* and *D. malaccensis* Among Indian *Derris* species, the roots of *D. ferruginea* from Assam contain rotenone (4 3%) and are important. But there is a variety of this species that is devoid of rotenone *Derris elliptica* was also grown in suitable localities.

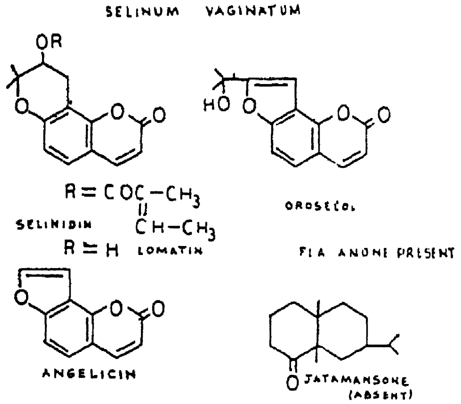


CHART 15. Components of *Selinum vaginatum*

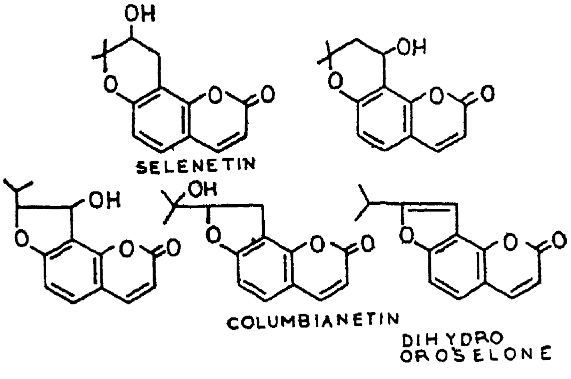


CHART 16 Structure of selinidin

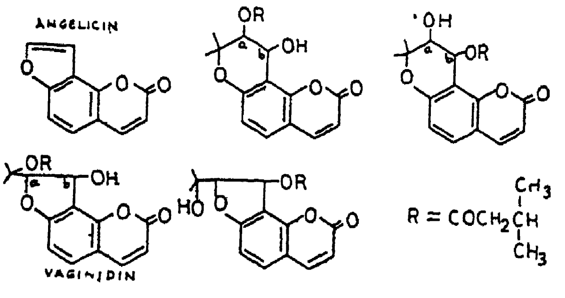


CHART 17 Structure of vaginidin.

However, the roots of *D. scandens* and *D. robusta* did not yield rotenoids but yielded members of the scandenin group which now number fairly large. They exhibit strong acid properties and are fairly stable in alkali. They have considerable toxicity though not so high as the rotenoids. Their full chemistry has been understood only recently and they are now known as derivatives of 3-phenyl-4-hydroxy coumarin having one or more C_5H_8 units Some of the typical members are given in the formulae (Chart 11).

Coumestrol group

These are also derivatives of 3-phenyl 4-OH coumarin but this hydroxyl group is involved in the formation of a fourth ring. The earliest member, wedelolactone, was isolated from *Wedelia calendulacea* by Govindachari *et al.* in 1956 and later from *Eclipta alba* also These are well-known vegetable drugs used for curing certain types of jaundice Besides this, *E alba* also contains nor-wedelolactone and trithienyl carbinol (Chart 12) and sulphur containing amino-acids. Possibly all these play some part in the curative action Later the simpler compound coumestrol was found in clover and it has marked oestrogenic properties. Many more members of this group have recently been isolated and several of them have been synthesized by convenient methods

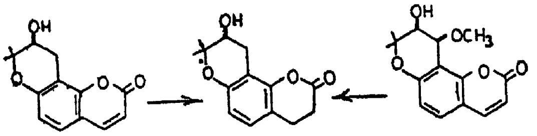
Novobiocin

This is an antibiotic produced by some *Streptomyces* species and has special value because it controls penicillin resistant organisms, particularly Staphylococci Its molecule consists of three parts, a central 4, 7(OH)$_2$ coumarin ring with the sugar unit linked in the 7-position and a para hydroxy-benzoylamide linked in the 3-position (Chart 13); it has been synthesized. Many similar coumarins of simpler type have been prepared by N. V. Subba Rao *et al.* of Osmania University and tested for antibiotic activity.

Neoflavonoids

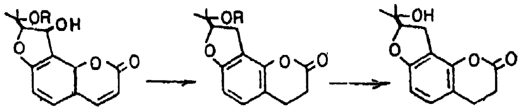
These are 4-phenyl coumarins. The first members, dalbergin and methyl dalbergin, were isolated from *Dalbergia sissoo* about the year 1950. Dalbergin has also been found in *D. latifolia*. Along with it, related quinone and quinol derivatives also occur, e.g. dalbergenone and latifolin (Chart 14). The neoflavonoid group has also increased in number in recent years. It may be mentioned that brazilin and haematoxylin which have been known as components of dyewoods for over 100 years and have been studied by Perkin and Robinson are now recognized as neoflavonoids.

In 1916 Simonis wrote his well-known book on the Chemistry of Coumarins. He listed only a few members of this group as occurring in nature. Many more have been discovered later and some of them have been mentioned earlier in this lecture. The family *Umbelliferae* (the common *Coriander* is a member of this family) is very prolific in the production of a large number of coumarin compounds. They are mainly derivatives of umbelliferone and 5-hydroxy umbelliferone with substituents in the 6- and 8-positions. Isoprene units are commonly present either as a chain or in the form of a ring involving the neighbouring hydroxyl groups. Even the 2-carbons present in simple benzofuran rings are considered to arise from the modification of the C^5 units and this idea has been used for the convenient synthesis of these compounds, e.g psoralen and xanthotoxin. Recently a very large number of new types have been isolated and studied in detail. As representative examples I propose to give the results of our study of two important plants of this family occurring in India.



SELENETIN METHYL KHELLACTONE

CHART 18 Absolute configuration of selinidin



VAGINIDIN TETRAHYDRO-OROSELOL

CHART 19 Absolute configuration of vaginidin

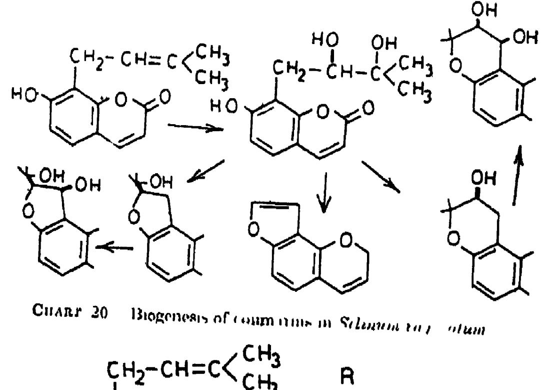
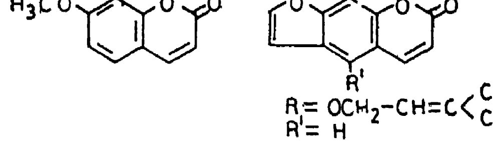


CHART 20 Biogenesis of coumarins in *Selinum vaginatum*



$R = OCH_2\text{-}CH{=}C\begin{smallmatrix}CH_3\\CH_3\end{smallmatrix}$; $R' = H$

$R = H$; $R' = OCH_3$

CHART 21 Components of *Seseli sibiricum* osthol, imperatorin and bergapten

Selinum vaginatum

More than 10 years ago there was great interest in the properties and components of Jatamansi (*Nardostachys jatamansi*) and we were supplied with samples of roots which were considered to be belonging to this plant. Since they did not yield jatamansone and were found to be different from the genuine root, we did not continue the investigation then, but more recently when more supply of the plant became available from Jammu and Kashmir we have made detailed study of it. It resembles Jatamansi only in general form and its colour is grey, whereas Jatamansi is brown Its microscopic characters are very different. It is now quite easy to differentiate between the two by carrying out the TLC of the petroleum ether extracts. *Selinum vaginatum* contains a number of coumarins (Chart 15) that are not present in Jatamansi and is lacking in the ketone jatamansone which can be extracted easily from Jatamansi and tested. There is another marked distinction. An alcoholic extract of *S vaginatum* gives a deep red colour with magnesium and hydrochloric acid indicating the presence of a flavonoid, whereas Jatamansi does not give this test. The flavonoid compound is new and named selenone. So far the association of coumarins with flavonoids has been considered to be rare.

From the petroleum ether extracts five coumarins could be isolated. Three of them are already known ones, angelicin, oroselol and lomatin (Chart 15). The other two, selinidin and vaginidin, are new compounds. The former is a major component and readily crystallizes out of the petroleum ether extract.

Selinidin is a highly crystalline compound melting at 97-98°, has the molecular formula $C_{19}H_{20}O_5$ and shows the characteristic properties of coumarins. Comparison of its spectra with those of known coumarins provided strong evidence for the presence of 7-oxygenated coumarin chromophore. It underwent hydrogenation to yield a tetrahydro derivative. IR spectral studies showed that selinidin was an ester of a hydroxy coumarin with an unsaturated acid. Though alkali hydrolysis gave tiglic acid, it was clear that originally angelic acid was present from the NMR spectral data; the change from angelic to tiglic is particularly facile. Important evidence for the structure of the hydroxy coumarin part (selenetin) was obtained by the dehydration of the hydroxy coumarin by acid, the product being identified as dihydro-oroselone (Chart 16). This left four possibilities for the constitution of selenetin; however, from other reactions and consideration the correct choice was made; it was clear that during dehydration of selenetin there was ring contraction also involving an interesting molecular rearrangement. About the same time as our work, Soine *et al.* obtained it as a free alcohol from another source and named it lomatin. Using this name selinidin will be lomatin angelate.

Vaginidin

The second new coumarin, vaginidin present in *S. vaginatum*, is also a highly crystalline compound melting at 133-34° but it has been far more difficult to isolate and required elaborate column chromatography. Its molecular formula is $C_{19}H_{22}O_6$, its spectral data and colour reactions suggested that it had the same chromophore as selinidin and was also an ester. It was therefore subjected to alkaline as well as acid hydrolysis and in both cases it yielded angelicin and isovaleric acid. Obviously besides ester hydrolysis there were other changes involving loss of groups. These observations gave rise to four possibilities for the structure of vaginidin. However, by the study of hydrogenation and NMR spectrum the correct choice has been made as shown in the formula (Chart 17). It is clear that during the hydrolysis retro-aldol cleavage takes place followed by loss of water.

Absolute configuration

In recent years a large volume of effort has been devoted to the establishment of absolute configuration of optically active compounds. In many cases the work has

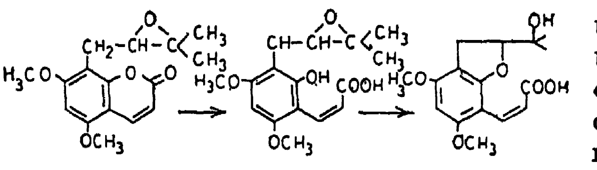


CHART 22 Structure of sibiricin.

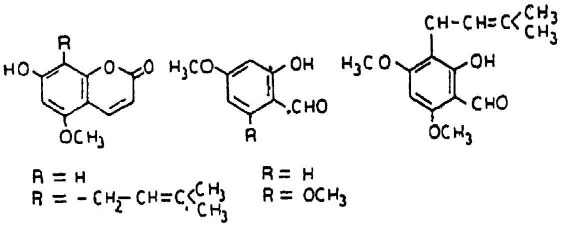


CHART 23 Synthesis of sibiricin.

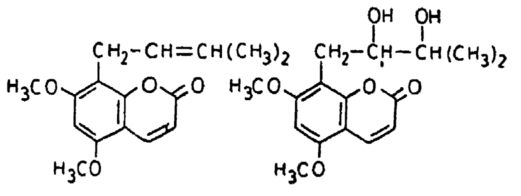


CHART 21 Coumurrayin and mexoticin

been rendered easy by the availability of reference compounds whose configurations have been definitely established and the new ones are studied by determining relationship with the known. The absolute configuration of selinidin and vaginidin has been settled in the following manner·

The absolute configuration at the 3′-position of selinidin and selenetin was established as (S) by correlation with cis-methyl khellactone (Chart 18). In vaginidin there are two asymmetric positions, 2′ and 3′. Since the compound could be converted into tetrahydro-oroselol by catalytic hydrogenation and ester hydrolysis, the configuration at 2′ was concluded to be (S) (Chart 19). From its properties and NMR spectrum vaginidin should have dis-configuration in 2′- and 3′-positions. Consequently it should have 2′(S) 3′(S) configuration. These studies seem to throw useful light in regard to the biogenesis of these compounds in plants.

Considerable interest has been shown on the biogenesis of these compounds. About 10 years ago we collected and correlated the structures of compounds containing the C_5H_8 units attached to coumarins and other types of compounds. These units derived from mevalonic acid enter reactive nuclear positions yielding first dimethylallyl derivatives (Chart 20). Subsequent transformations are indicated by the subsequent charts.

In some compounds there are two hydroxyls; the second ones in the benzylic position seem to arise by stereospecific oxidation. Angelicin represents a type in which oxidative cyclication involves loss of three carbon atoms.

Seseli sibiricum is another plant belonging to the Umbelliferae and occurring mainly in Kashmir. It is used for blending beverage and as medicine for livestock The umbels of this plant have yielded, besides the well-known compounds —osthol, imperatorin and bergapten (Chart 21), a new member, sibiricin, which is a representative of an important type. It has the molecular formula $C_{16}H_{18}O_5$ and has the chemical and spectral properties of a 5, 7-oxygenated coumarin with an epoxide unit. Two important, reactions which established its structure are: (1) conversion into a glycol (sibiricin glycol) when treated with 1 per cent oxalic acid and (2) formation of sibiricic acid by alkali hydrolysis involving a rearrangement (Chart 22). A significant observation is that the above glycol is optically active and appears to be identical with mexoticin recently isolated from *Murraya exotica* (Chart 24).

Epoxide formation is the result of easy oxidation of unsaturated compounds in plants and epoxides occur frequently. The above structure of sibiricin has been confirmed by synthesis (Chart 23). Synthesis of such types is somewhat difficult and has been engaging our attention. A direct synthesis would be by the introduction of isoprene unit in 5-methoxy-7-hydroxy coumarin. But this does not take place in a satisfactory manner and has therefore been done in an earlier stage (salicylaldehyde stage) and coumarin ring closed and epoxidation effected finally.

The dimethyl-allyl coumarin, prepared as an intermediate in the synthesis of sibiricin, has been very recently found to occur as a natural product in the ripe fruits of *Murraya paniculata* and has been named coumarrayanin (Chart 24). The components of *Murraya* species indicate paths of biogenesis.

Conclusions

In the progress of the chemistry of natural products during the past century and a half, coumarins have played an important part. We have had a large number of occasions to deal with them in the course of our own investigations.

The parent compound coumarin was isolated by Vogel in 1820 from tonka beans. Its synthesis was effected by W H Perkin in 1868 and his method is even now adopted with some essential improvements. It has become one of the most important and useful among aromatic compounds and its annual production is very large. Towards the end of the last century and early this century considerable work was done on the properties and reactions of coumarins and on the methods of their syntheses. The additive reactivity of the double bond in coumarins and the geometrical isomerism in acids derived from them led eventually to an understanding of the biogenesis of the naturally occurring members.

The study of Indian and Egyptian drugs used for skin diseases that began with the thirties of this century led to detailed investigations on the furanocoumarins and their photodynamic properties and to their easy syntheses. The next decade witnessed the discovery of dicoumarol and its important anticoagulant property and the development of other drugs in this line. Some coumarins have anti-veratrinic and anti-arrythmic action and some are capable of being used against radiation damage.

Many species of *Derris* do not contain rotenoids but members of the scandenin group which are 3-phenyl-4-hydroxy coumarins having one or more isoprene units. A related group consists of derivatives of coumesterol having important physiological properties. Novobiocin is an important antibiotic derived from 4-hydroxycoumarin. The discovery of dalbergin, a 4-phenyl coumarin in the woods of *Dalbergia* spp., initiated the study of a new group of compounds called 'neo-flavonoids'. In recent years the study of the plants of the family Umbelliferae has led to the isolation of a large number of coumarins with isoprene units disposed in various ways. *Selinum vaginatum* and *Seseli sibiricum* contain a number of these compounds in interesting association Selinidin, vaginidin and sibiricin are important new members that are representatives of different structural types.

Acknowledgement

I wish to express my thanks to Dr P Srinivasa Rao for help in the preparation of the manuscript.

A USEFUL DEVELOPMENT IN THE CHEMISTRY OF FLAVONOIDS AS NATURAL PRODUCTS

T R Seshadri

(delivered at Bombay, January 1969)

Importance of *Ginkgo biloba* (maiden-hair tree)

Ginkgo biloba (maiden-hair tree) is a tree of great botanical and chemical interest. It is the only surviving species among Ginkgoales which were widespread in the very distant past between 60 and 250 million years ago. It has apparently remained unchanged over geological ages and it has therefore been called a 'living fossil'. It has long been cultivated in temple gardens of Japan where it is considered sacred. Not only is the tree beautiful but the green fruits are eaten after frying. The flesh of the ripe fruits is found to contain toxic phenols. The tree has been introduced into European countries and the USA

The extract of the leaves of this tree has been reported to have medicinal properties and it is now being marketed in West Germany in forms suitable for oral administration and injection. It is considered to possess blood flow increasing and vascular widening properties and is recommended for use in hormonal, nervous, vascular, blood flow and nutritional disorders.

The special chemical components of these leaves have been studied intensively during the past ten years and their structures have been established. They are known as 'biflavonoids' in whose molecules two C_{15} units are linked together. In view of the important medicinal properties attributed to the leaves we have recently examined Indian plant sources for compounds of this type and have obtained some useful results.

Before proceeding further, it may be useful to mention earlier discoveries on the medicinal uses of flavonoids. These polyphenols were originally valued as mordant dyestuff and this use has become obsolete after the introduction of synthetic dyestuffs. But their importance has continued for other reasons. One of these is their vitamin P property. This was discovered by Professor Szent Georgyi more than 30 years ago At the present time Rutin, which is obtained on a large scale from buck-wheat and eucalyptus leaves, is used in medicine Similarly the bioflavonoids, hesperidin and naringin obtained as by-products of the citrus industry are employed for the maintenance of capillary integrity, control of spontaneous abortion and to aid in surgery and wound healing.

Ginkgetin and related compounds. The leaves of *G. biloba* were first examined chemically by Furukawa in 1932. He proposed the structure of 5, 8-dihydroxy-4′-methoxy flavone (4′-methoxy primetin) for the chief component which he labelled as 'Compound B'. This was later on named 'ginkgetin' by Baker who also showed that it was different from synthetic—4′-methoxy primetin. The study was progressing for over 25 years without conclusive results. The main difficulties were as follows: (*i*) the leaves yielded a mixture of three closely related compounds and their separation was originally difficult; (*ii*) much of the earlier study was carried out with mixtures; (*iii*) there was also difficulty of correctly determining the molecular size of these compounds. Eventually it was concluded that they were biflavonoids containing two flavonyl units and their constitutions were arrived at by the very extensive work of Japanese and British workers.

The crude material contained at least three related natural products of which

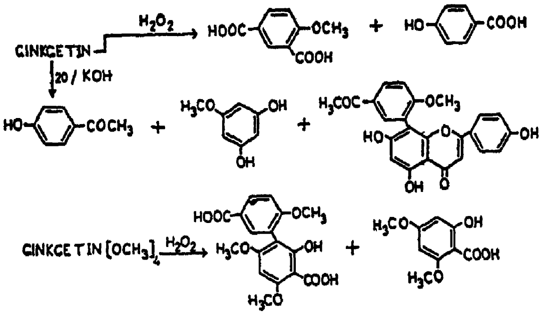


Chart 1. Chemical degradations of Ginkgetin

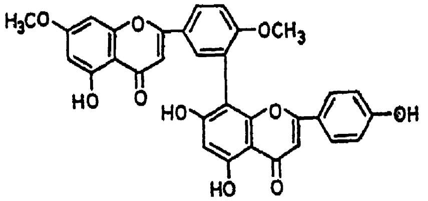


Chart 1a. Ginkgetin

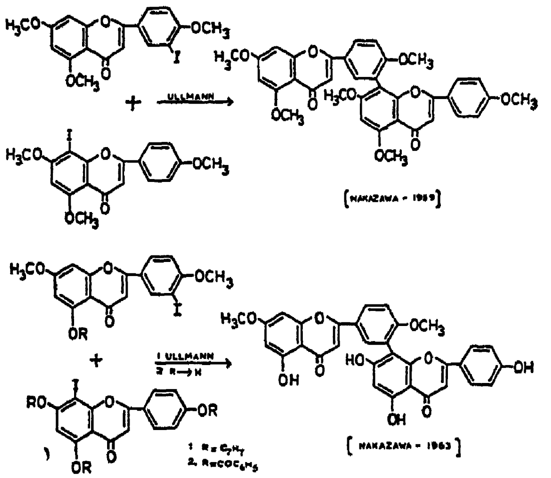


Chart 2 Synthesis of Ginkgetin and its methyl ether.

two major ones were ginkgetin and isoginkgetin. It was later shown that these compounds could be comparatively easily isolated by taking advantage of Nakazawa's observation that ginkgetin formed a rather insoluble crystalline potassium salt. Treatment of the mixture with aqueous potassium carbonate gave the sparingly soluble potassium salt of ginkgetin and acidification of the mother liquor gave isoginkgetin. Later the surprising observation was made that the mixture could be easily separated by fractional crystallization from acetone. Since by the use of the Rast method for the determination of molecular weight satisfactory results were not obtained, the modified Menzies-Wright ebullioscopic method was used and the molecular formula of ginkgetin was found to be $C_{32}H_{22}O_{10}$ and it contained two methoxyl and four hydroxyl groups.

The UV spectra of ginkgetin tetraacetate and tetramethyl ether indicated that they are derivatives of apigenin. Moreover, the intensities of the absorption bands were approximately double those of the monomeric apigenin derivatives This demonstrated the presence of two isolated flavonoid units per molecule. Further studies of spectra particularly IR and colour reactions gave more information about the location of groups. But definite information was obtained by chemical degradations. The most important of these are given in Chart 1.

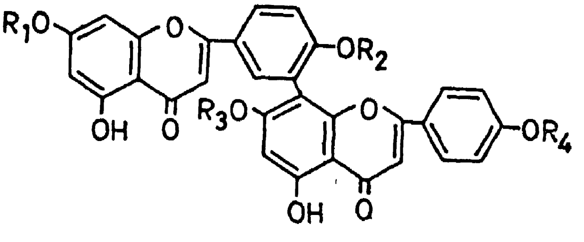
They led to the conclusion that the flavonyl units had C-C linkage and were linked at 3′ and 8″ -positions. The position of the methoxyls was not only indicated by the nature of the fission products but also confirmed by the study of UV spectra in the presence of bases. The constitution proposed by Baker and co-workers in the year 1959 was 4′, 7-O-dimethyl-3′, 8″ -biapigeninyl (Chart 1*a*).

Nakazawa effected a synthesis of ginkgetin tetramethyl ether in 1959 by a mixed Ullmann reaction between 3′-iodo-5, 7, 4″-trimethoxyflavone and 8-iodo-5, 7, 4′-trimethoxyflavone using copper in dimethyl formamide medium. One of the products was found to be identical with the tetramethyl ether of natural ginkgetin. In 1963, Nakazawa synthesized ginkgetin itself as follows: He used for the protection of the free hydroxyl groups in the components benzyl and benzoyl units and these were conveniently removed later on to yield ginkgetin (Chart 2).

As already mentioned two more related compounds (partial methyl ethers) have been isolated from *G. biloba* leaves. They are isoginkgetin and bilobetin. The former is an isomeric dimethyl ether and the latter a related monomethyl ether. Soon many other methyl ethers of this group were isolated. The parent compound of all these ethers is called 'amentoflavone'. Originally it was considered to be rare; now several sources have been found. The trimethyl ether 'sciadopitysin' is of importance; it was isolated by Kariyone and Kawano in 1956 and their extensive work on it was complementary to the work of Baker *et al* (1959) on ginkgetin (Chart 3)

No	Name	R_1	R_2	R_3	R_4
1.	Amentoflavone	H	H	H	H
2.	Bilobetin	H	CH_3	H	H
3	Podocarpus-flavone A	H	H	H	CH_3
4	Sotetsuflavone	H	H	CH_3	H
5.	Ginkgetin	CH_3	CH_3	H	H
6.	Isoginkgetin	H	CH_3	H	CH_3
7.	Podocarpus-flavone B	CH_3	H	H	CH_3
8.	Sciadopitysin	CH_3	CH_3	H	CH_3
9	Kayaflavone	H	CH_3	CH_3	CH_3
10	Amentoflavone tetramethyl ether	CH_3	CH_3	CH_3	CH_3

CHART 3. Amentoflavone series.



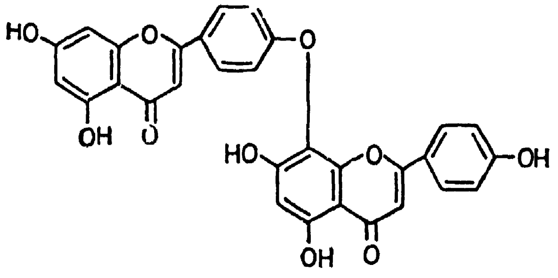


CHART 4. Hinokiflavone

Hinokiflavone: A different type of biflavonoid was isolated by Kariyone and Sawada in 1958 from *Chamaecyparis obtusa.* It was named 'hinokiflavone' based on the Japanese name of the plant 'hinoki' (Chart 4). The constitution of this compound was arrived at by Kawano in 1960. It was also a dimer of apigenin, the molecular formula being $C_{30}H_{18}O_{10}$; it had no methoxyl groups. It formed a pentamethyl ether and pentaacetate. The UV pattern was different from that of the earlier known biflavonyls but the UV of the complete methyl ether agreed with the UV of ginkgetin tetramethyl ether. By ferric colour reaction and IR data two hydroxyls were inferred to be in 5 and 5″ positions. From the degradations of hinokiflavone and its pentamethyl ether a diphenyl ether constitution was arrived at (Chart 5).

Among the products of degradation compound (III) having a diphenyl ether structure was important. It could be converted by methylation followed by oxidation and decarboxylation into 2, 4, 6-trimethoxy diphenyl ether. This could be synthesized by the Ullmann condensation 2, 4, 6-trimethoxy-bromolbenzene and potassium phenoxide. Thus the diphenyl ether structure was proved (Chart 6).

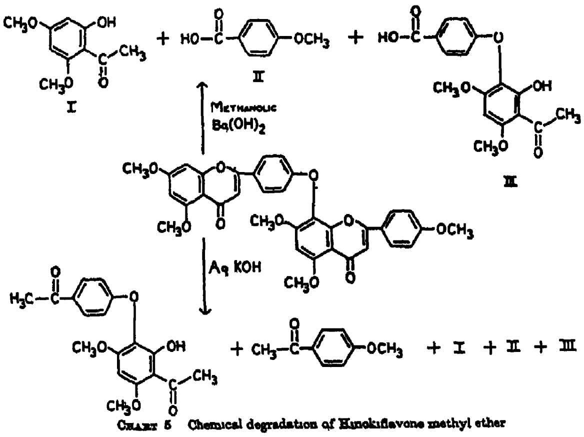


CHART 5 Chemical degradation of Hinokiflavone methyl ether

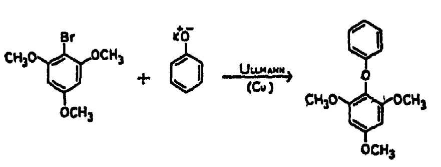


CHART 6. Synthesis of 2, 4, 6-trimethoxy diphenyl ether

Since compound (III) gave positive reaction with Gibbs' reagent there was indication that the diphenyl ether link was ortho to the hydroxyl and the alternative possibility was eliminated. We attempted the synthesis of hinokiflavone pentamethyl ether through the Ullmann condensation of 8-iodoapigenin trimethyl ether and potassium salt of 4′-hydroxy-5, 7-dimethoxyflavone There was partial demethylation in this reaction and remethylation was done to obtain the pentamethyl ether. The resulting product was identical with hinokiflavone pentamethyl ether. However, Nakazawa has recently claimed that he has synthesized both 4′, 8″ and 4′, 6″ -isomers by unequivocal methods indicated in the formulae given below and only the 4 , 6 -compound agrees with the natural sample. This is explicable if in the above Ullmann synthesis the partial demethylation that takes place leads to isomeric change of the biflavonoid system. This is supported by his observation that synthetic 4′, 8″-biflavonyl compound gives natural hinokiflavone when boiled with hydroiodic acid. On this basis, the structure of hinokiflavone and the partial methyl ethers require revision (Chart 7).

No	Name	R_1	R_2	R_3
1.	Cryptomerin A	H	H	CH_3
2.	Isocryptomerin	H	CH_3	H
3.	Neocryptomerin	CH_3	H	H
4.	Chamaecyparin	CH_1	CH_3	H
5.	Cryptomerin B	H	CH_3	CH

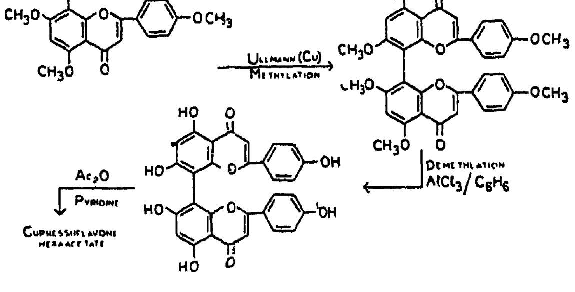
CHART 8. Hinokiflavone series

Hinokiflavone is now found to occur fairly widely in nature; several of its mono and dimethyl ethers were also found (Chart 8).

Cupressuflavone: While looking for Indian sources of biflavonoids, we isolated from the leaves of *Cupressus torulosa* and *Cupressus sempervirens* a new biflavone which belonged to a C-C type and called it cupressuflavone. In 1964, it was assigned the constitution of 8, 8″-biapigeninyl. Its UV spectrum was similar to that of apigenin (peaks at 226, 274 and 330 mμ). The intensity of the UV maxima suggested that cupressuflavone was a biflavone. IR spectrum indicated the presence of chelated hydroxyl (s). Its molecular formula was found to be $C_{30}H_{18}O_{10}$. It did not contain any methoxyl or C-methyl groups. It gave a hexamethyl ether and hexaacetate. On oxidation cupressuflavone hexamethyl ether yielded anisic acid as the only isolable entity. The NMR spectrum of the complete methyl ether of cupressuflavone was symmetrical. From the coupling pattern and the chemical shifts of the aromatic protons, it was inferred that oxygenation was at 5, 7, and 4′-positions. On these considerations the following constitution was proposed (Chart 9).

The decision between these two structures was sought to be made by the synthesis starting from 8-iodoapigenin trimethyl ether and subjecting this to Ullmann condensation. The synthetic hexamethyl ether was identical with the natural sample and from it cupressuflavone itself and its hexaacetate were obtained. But the possibility of rearrangement during these reactions has not been fully eliminated (Chart 10).

Recently cupressuflavone tetramethyl ether (7, 7′ 4′, 4‴-) and dimethyl ether (4′, 4‴-) were isolated by Rahman *et al.* (1968) from the leaves of *Araucaria cunnighamii* and *A cookii*. These compounds are important because they exhibit optical activity arising from restricted rotation.



Biogenesis: The biogenesis of the biflavonoids seems to involve oxidative coupling of polyphenols. It has been well known for a very long time that phenols are readily oxidized by many different reagents. The products are complicated mixtures of dimeric, polymeric and quinonoid types of compounds. This method is useful for the synthesis of simple and complex compounds when coupled with efficient methods for the separation of the complex mixtures. Phenol coupling has been suggested as an important step in the biogenesis of different classes of natural products and has stimulated intensive research. In general, the dimeric and polymeric oxidation products can be formulated by abstracting one hydrogen atom from the starting phenol and coupling together these intermediates by C-C and C-O bonds at active nuclear positions o- and p- to the hydroxyl. We owe mainly to Barton (1956) the development of these ideas leading to the synthesis of usnic acid and many others by oxidative phenol coupling.

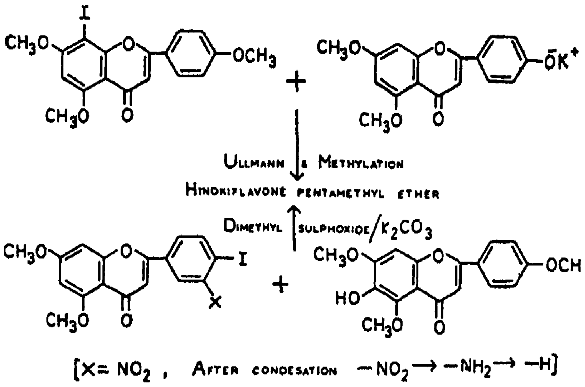
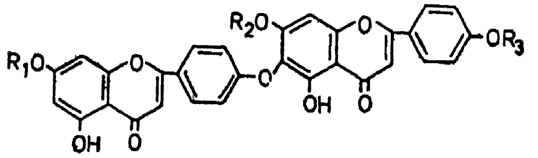

I
CH3O
OCH3
CH3O
O
+
CH3O
OK+
CH3O
O
Ullmann & Methylation
Hinokiflavone pentamethyl ether
Dimethyl sulphoxide/K2CO3
CH3O
I
X
CH3O
O
+
CH3O
OCH
HO
CH3O
O
[X= NO2 , After condensation —NO2→—NH2→—H]

Chart 7 Synthesis of Hinokiflavone methyl ether



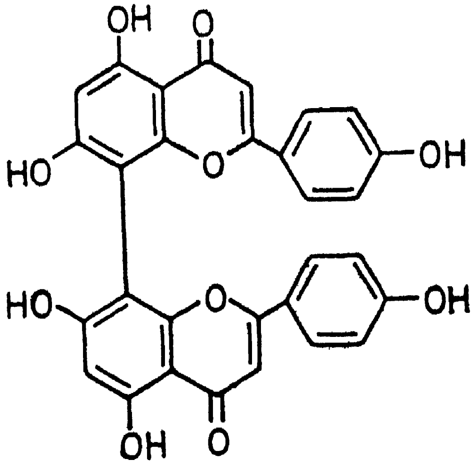


Chart 9. Cupressuflavone

The above considerations make it probable that the biflavonyl structure could arise by oxidative coupling of the monoflavonoid precursor apigenin. The oxygenation pattern of the precursor restricts the interflavonyl linkage to 6, 8 and 3'-nuclear positions (Chart 11). In the formation of ethers, each of these positions may be linked with any of the three oxygens of the hydroxyl groups. However, among the large number of possibilities only a few are so far known and this may be due to some factor of preferential activation A later stage of methylation can yield the known methyl ethers. Support for this scheme is provided by the fact that in a number of plants apigenin is also present along with the biflavonyl pigments. Some experiments in our laboratory using one electron transfer reagents confirm the scheme

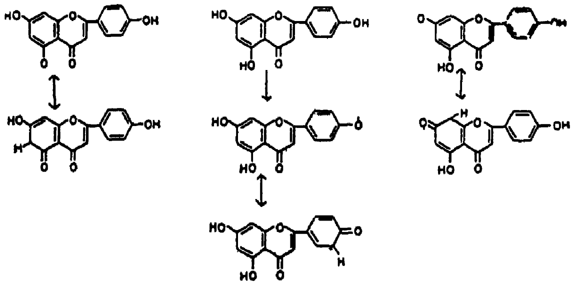


Chart 11 Free radical intermediates of oxidative coupling

Study of Casuarinaceae: The study of the chemical components of the gymnosperms, particularly the conifers, will be useful for their possible application as drugs. There is also interest in regard to the taxonomy of the plants since they contain biflavonoids as special components. I may mention the study of *Casuarina* as a typical example. This genus has about 40 species chiefly found in Australia and in Indo-Malayan region. Of these, *Casuarina equisetifolia* is commonly cultivated in India. There is some difference of opinion regarding the taxonomic position of the genus. Sawada examined the leaves of *Casuarina stricta* and found that hinokiflavone is present in them. Earlier investigations had shown that the leaf-wax of this plant gives on hydrolysis juniperic acid (16-hydroxy palmitic acid) another typical gymnosperm constituent. The occurrence of these two gymnosperm compounds in the leaves of *C. stricta* lent support to the view that Casuarinaceae is close to the gymnosperms. However, Batesmith (1962) reported that *C. cunnighamii* contains only kaempferol and quercetin. Our re-examination of the leaves of Indian trees revealed the presence of cupressuflavone We also examined *Casuarina suberosa* and it contained hinokiflavone. These results may help to settle the taxonomic position of the genus (Chart 12).

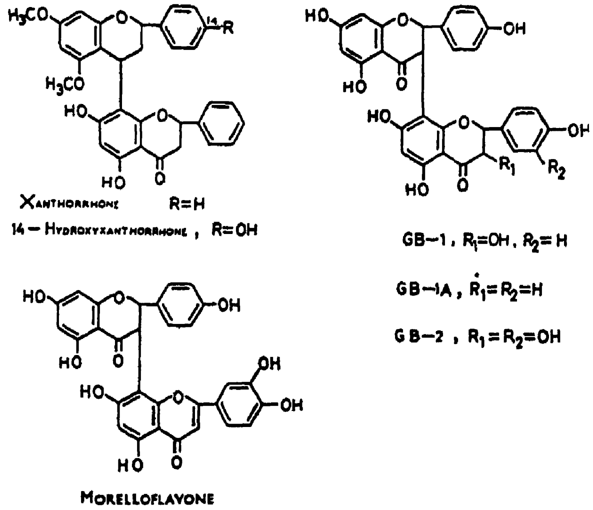
No	Source	Biflavones Identified
	CUPRESSACEAE	
1	C. funebris	C, H, A, H-7″OCH$_3$
2	C. sempervirens	C, A.
3.	C. torulosa	C, A, H
4	Biota orientalis	H.
	CASUARINACEAE	
1.	C. cunninghamiana	C,
2.	C. suberosa	H,

C—Cupressuflavone H-7″OCH$_3$—Isocryptomerin
A—Amentoflavone H—Hinckiflavone

CHART 12 Chemical components of some species of Cupressaceae and Casuarinaceae

Study of mass-spectral fragmentation: During our study of the biflavonyl pigments of Cupressaceae we have found the presence of partial methyl ethers of the three known types of biflavones and also new types of biflavones. They are present in very minor amounts and chemical degradation cannot be carried out for arriving at their structures. Mass spectra can be utilized in these cases and we have therefore made a critical study of the three types of biflavones known. Since the hydroxy compounds are very high melting the spectra of their complete methyl ethers have been recorded. From such a study, we can distinguish diphenyl and diphenyl ether type of biflavones and the position of the methoxyls can also be fixed.

Other biflavonyl compounds: Other modes of biflavonyl linking has been shown to be possible. Recently Jackson *et al.* (1967) isolated three compounds of a new dimer that could be called flavanonyl flavanone (biflavanone) from the heartwood of *Garcinia buchanii*. This involves the linking of two flavanone units at 3 and 8 positions. Their constitutions were arrived at by UV, IR, NMR and mass spectra. In these compounds both the units consist of flavanone units. Morelloflavone, a flavonyl-flavanone, isolated by Venkataraman *et al.* (1967) from the pericarp of the seeds of *Garcinia morella* contains a linking between a flavanone and flavone Xanthorrhone and 14-hydroxy xanthorrhone which were isolated by Pelter *et al.* (1967) from Australian xanthorrhea contain a flavanone and flavan units (Chart 13).



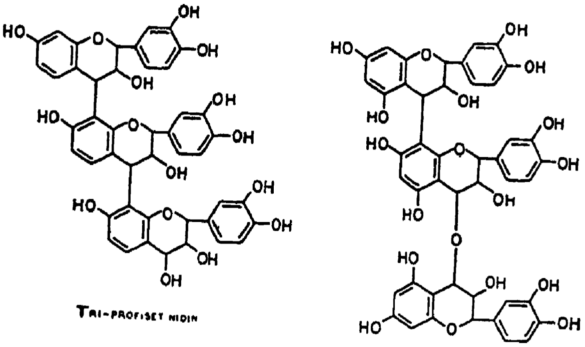
XANTHORRHONE R=H
14—HYDROXYXANTHORRHONE, R=OH

GB—1, R$_1$=OH, R$_2$=H
GB—1A, R$_1$=R$_2$=H
GB—2, R$_1$=R$_2$=OH

MORELLOFLAVONE

CHART 13 Recent biflavonyl compounds

More widespread and important is another group of this type which has also been studied with some clarity during the past ten years. They are the proanthocyanidins (Chart 14). Under the name leucoanthocyanidins, they had earlier attracted considerable attention as components of tanning materials and as astringent principles in foods and drugs. They are also capable of readily forming polymeric resins and a number of them have been isolated in recent years. They are made up of either two leucoanthocyanidin units or of leucoanthocyanidin and catechin. But the linking is easily broken by mineral acids, yielding eventually the corresponding anthocyanidin and catechin. Some typical examples are given in Chart 14 Frequently we obtain trimers and higher polymers.


Tri-profisetinidin

Tri-procyanidin

Chart 14 Proanthocyanidins

Acknowledgement

I convey my thanks to Prof V V S Murti and Mr S Natarajan for help and Dr S Kedarnath for the gift of authentic pictures

GOVERNMENT AND THE SCIENCE ACADEMIES

T R Seshadri

(delivered at Bombay, 1969)

This is the last occasion for me to speak as the President of this august body. Therefore, I feel I should give expression to a few general thoughts that have been exercising my mind. I have been earlier talking to the Fellows of the Institute individually and in groups on these problems but rather informally.

As Fellows of the National Institute, we have been doing our best to add to the strength and usefulness of the Institute and make it a fully representative Academy of Indian science which should be held in high regard not only by the scientists of the country but also by the Government and the people. During the last two years of my Presidentship, I have tried my utmost to strengthen the organisation and have noticed certain disturbing features. I am sure, you will all agree that the Institute has an important role to play in the Indian body politics particularly in the advancement of science and technology and in their applications to the welfare of the nation. It is one of its responsibilities to provide leadership to the scientific community and create and develop public opinion by example and by precept The prosperity and security of nations, irrespective of the social or political systems, are determined largely by their scientific capability and industrial strength Hence governments have been deeply involved in the growth of science and have allotted sizable budgets for this purpose. This activity is bound to grow further in our country.

1. The place of the scientists in government is, therefore, taken for granted and they have to participate in decision making and discharging executive functions. This is not without its repurcussions. There exists a possibility of individuals being placed in charge of great responsibilities, but not measuring up to them. It looks as if an efficient method is not employed to prevent this possibility from taking place. Various non-scientific interests seem to play their role. There is also the danger of individuals assuming roles far beyond

their competence and jurisdiction An effective safeguard is the development of the machinery of consultation so that no single individual should come to enjoy the privilege of advising the government and taking decisions of importance merely by virtue of his position. This arrangement can work effectively only by utilising the services of an independent science academy. Often times, the existence of a number of national academies of science in India is raised, as if this factor is a serious impediment. I may mention that even the United Kingdom, they have the Royal Society of London and the Royal Society of Edinburgh. In many other countries, there are more than one academies. The fact of multiple academies has not prevented the governments of those countries from utilising the services of the principal institutions they have recognised.

Although, as early as 1945, the Government of India declared the National Institute of Sciences of India as the premier Science Academy in the country, consultation of the Institute by the Government has been sporadic and half-hearted The promised Act of Parliament in regard to the National Institute of Sciences of India is still to materialise. There has no doubt been an encouraging and a noticeable change in government's attitude recently, but I am afraid it has not been adequate to meet the needs of the situation and needs of a fast changing country.

2. The other remark which I wish to make appears to me even more important. This relates to the Fellows themselves. The question has often been raised if all the Fellows have given full loyalty to the National Institute without yielding to other narrow sectional or group interests. Criticisms of our elections have at times been voiced, that there are too many or too few Fellows and that some scientists have not been elected. Such criticisms are not uncommon in a democratic set up. Though the criticisms are without any basis we have discussed them objectively and taken steps to remedy possible lapses Our system of election is the same as that of the highest Academies of the world and has stood the test of time and experience. Every scientist in this country who has scientific achievement and good standing to his credit is eligible for election. The application of rigorous standards endows prestige to the Fellowship. I am afraid, the claim that scientists, simply because of their holding positions of influence or governmental responsibility at high levels, should be considered qualified for election as Fellows of this Institute, is not sustainable. The National Institute will cease to be a science academy of repute if considerations other than scientific achievements and standing come into play in the election of Fellows.

I appeal to all Fellows of the Institute who are holding responsible positions in scientific organisations in the country and in Government to carry with them the interest of the National Institute and make use of the National Institute in their organisations by associating it with their activities. We are in the throes of large changes in science and in our scientific institutions. In the past we have leaned heavily on beaurocratic set up involving considerable secrecy and closed-door attitudes. There may be fear that should an independent science academy function effectively it may express opinions, often in criticism, of the state policy or practice. Expression of such opinions by a scientific academy should be welcome in our democratic society. They tend to strengthen rather than weaken the government and the society.

Among our Fellows are scientists who are in-charge of some of the major scientific organisations of the country. Not unnaturally, there may be some differences among them in matters of administrative concern, but I feel these differences need not be brought into the even atmosphere of the NISI. On the contrary, it should be used as a forum to smoothen such differences and for setting things in their right perspectives. With prayerful hearts and vigilant minds we should work to achieve the highest ideals of NISI.

Dr Atma Ram, FNA*

(Elected to the Fellowship 1953; President 1969-70)

Dr Atma Ram was born on October 12, 1908 in Uttar Pradesh and received his PhD degree from University of Allahabad in 1936. He was the Chairman, National Committee on Science and Technology; Secretary, Government of India, Department of Scientific and Industrial Research, Cabinet Secretariat; Director General, CSIR and Director, Central Glass and Ceramic Research Institute, Calcutta. Dr Atma Ram was the General President, Indian Science Congress (1967-68); President, Indian Science News Association (1965-67); President, Ceramic Society (1952-53); Fellow, Institute of Chemists, India; Honorary Fellow, Society of Glass Technology, Sheffield; Member, International Commission on Glass (1948). He was the recipient of Padma Shri (1959); first Scientist to receive S S Bhatnagar Medal (1959) of the Indian National Science Academy (then National Institute of Sciences of India) and Honorary Doctorate degree from Lenin Soviet Technological Institute, Leningrad.

One of the most distinguished applied scientists of India, Dr Atma Ram was ranked among the world's leading glass technologists. His most important achievement had been the development of the process for the manufacture of optical glass, which is one of the prized strategic materials for defence and in industry and is a closely guarded secret, for strategic reasons, of a few advanced countries of the world. The Central Glass and Ceramic Research Institute developed under the leadership of Dr Atma Ram. The Institute is now ranked among one of the world's distinguished centres of glass research. Other contributions which the Central Glass and Ceramic Research Institute made under his leadership are in line with his declared policy of achieving self-reliance. The production of foam glass, selenium-free red glass and insulating bricks from waste mica are some such processes developed by him which have generated a chain of new manufacturing possibilities in India. His work on the origin of colour in copper-red glass is regarded as one of the outstanding contributions to fundamental research on glass

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*died in 1983

SCIENCE—OUR NEW RESPONSIBILITY

ATMA RAM

(delivered at Kharagpur, 1970)

I was hoping to speak on the occasion of the Anniversary meeting of the Institute on a subject in which I have been engaged for about a decade, namely on the origin of colour in copper ruby glasses and also to avail of the privilege as President to refer to a few matters connected with the working of the Institute. I deeply regret that owing to sudden illness, I have been prevented from discharging my duty in person and I hope the Fellowship will forgive me for my absence. I should like to convey to the Fellowship best wishes for a Happy New Year.

Before I start I would like to refer to the fact that the Institute has now a new name. As the Fellowship is aware, the Council of the Institute had, after long discussions, recommended last year a change in the name of the Institute to 'Indian National Science Academy'. This recommendation of the Council has been approved by the Fellowship as required by the rules of the Institute. The formalities for the change-over are in the process of being completed.

At the Annual General meeting held on October 10, 1969 I had referred in my review to the important responsibilities that the Institute has now assumed As you are all aware the Institute is the national adhering body on behalf of India to the International Council of Scientific Unions and we have constituted Indian National Committees corresponding to the 15 International Scientific Unions affiliated to the ICSU, 3 Special/Scientific Committees set up by it, and 1 Inter-Union Commission. This responsibility devolves on the Institute the work of choosing Indian delegations to the Annual Conferences and Symposia organised by these International Unions. I would like to emphasise that as the premier scientific society in this country we should not restrict ourselves merely to constituting delegations and deputations. We should now seriously address ourselves to the task of making the National Committees focal points of national activities for advancement of science in our country. The National Committees should, therefore, really become working groups and should function in a continual manner bringing out papers on the basis of their deliberations which could provide guidance to the scientific community in the country.

The other assignment given to us is about the Indo-Soviet Co-operation in science working with our opposite number the Academy of Sciences of the USSR. A symposium on the chemistry of natural products is scheduled to be held in Delhi under this programme in February this year and a strong delegation of Soviet scientists is expected to participate. The Fellowship may recall the symposium held on this subject in Tashkent in 1968 with an Indian delegation led by Professor TR Seshadri, past President of the Institute Fellowship is already aware of the scheme of support to basic sciences now being operated by the Institute. This again is an activity which, I am sure, will grow a great deal in future.

One of the features of post-war scene in the scientific world has been the increasing growth of bilateral and multilateral scientific exchange programmes between various countries involving their national academic and professional bodies. India has also got into this international movement in a fairly big way. For instance the Council of Lcientific and Industrial Research has several bilateral agreements with corresponding or similar bodies in some other countries. I venture to suggest that the National Institute should also take increasing interest in this sort of activity and make good use of these agreements to develop international contacts at working level. These agreements could be of immense value if they are pursued with imagination.

Impressed by the need of the approach, I recently wrote a letter to Professor Lord Blackett, President of the Royal Society suggesting collaboration in scientific matters between the Royal Society and the National Institute. Professor Blackett wholeheartedly welcomed the suggestion. As a first step, both the Societies will let each other know about the visits of the Fellows to the respective countries to make personal contacts, deliver lectures and hold discussions. A beginning has already been made and Prof C Auerbach, an eminent geneticist and Fellow of the Royal Society delivered a stimulating lecture at the Institute last week, Professor Lord Todd and Sir Joseph Hutchinson will deliver lectures this month, and I hope Professor Kurt Mendelssohn may also be able to do so.

The Institute is also taking steps to develop co-operation with the National Academy of Sciences of the USA and a workshop on the management of research institutions and related subjects is being jointly organized in India to be held in February.

I am mentioning all these points to emphasise the increasing importance of the Institute in our national affairs. In order to remain in the forefront of Indian scientific affairs, the Institute must assume a more dynamic role and influence public opinion in the country on matters concerning and affected by science and technology. It should continuously act in a manner to provoke thinking, discussions and debates on many issues which are concerned with science and scientists. It is not that as an Academy it should remain content with the government assigning responsibilities to it or referring matters to it for views. In my view we have a responsibility to consider issues affecting science and scientists and make our views known whether they were liked or not. Ours is a scientific body and we should express our views based on objective analyses and studies. This needs considerable organisation and hard work. We have already instituted a few such studies during the last couple of years on matters relating to policies; but I think we have to go a long way to make ourselves felt.

At a time when science and technology are assuming increasing importance in our national life, the role of our Institute will be appreciated better if it plays its part in shaping not only scientists' opinion but public opinion in general on matters related to science and in particular to the uses of science in which people should be induced to take interest in a growing democracy. I wish particularly to refer to the resolution adopted only a few days back in Bombay by the ruling party on science and technology. This is a welcome sign, and one may safely forecast that before the next general election, all the important political parties will come forward stating their viewpoints on science and technology. This has happened in other countries too. Both the Labour and Conservative parties in the UK have frequently made their views known on their approach to science and technology in their country. One of the very readable documents which I have come across is entitled "Signposts of the Sixties" issued by the Labour Party on the eve of one of the general elections in the UK. While we should welcome the leading political parties to state their views on science and technology, we as scientists have also to be careful that these matters are not dealt with purely from the point of view of politics or mass appeal. I think the professional societies have a responsibility to ensure that a situation does not arise where vague opinions are expressed without being firmly based on scientific and rational thinking. The National Institute of Sciences, in my view, has a heavy social responsibility in this regard which must be discharged with care and caution Opinions which may be popular need not be necessarily the right opinions, and *vice-versa*. Scientists may have no political ambition and I think most scientists do not have, but they have a role to play in national affairs. This role must be played well.

This leads me on to a few thoughts on science policy There is considerable discussion and expression of opinions in regard to science policy in India I am afraid there is a certain amount of vague generalisation In terms of a general national science policy, I do not think we can really do anything better than what has been stated in the Science Policy Resolution of 1958 I doubt if in substance, Jawaharlal Nehru's draft can be improved. It is a valuable statement of objectives, of good intentions well stated in as few words as possible at a general national level But I think to make the policy statement operative, the major scientific organisations must frame their own policies on basis of and as an integral part of the Science Policy Resolution so as to spell out their goals and how they propose to realise them Each research institute, in my view, should formulate similar guiding lines of its own. Our institutions and individual scientists can then work with a greater sense of purpose and a more satisfying sense of achievement.

The second point which I wish to make in regard to science policy is the confusion that still exists in our country about science and technology. They are no doubt overlapping and interwined, often difficult to disentangle; but I think it is necessary for the scientific community to understand and make others understand that science and technology though interdependent are not one and the same thing and they have their distinctions. Why has this difficulty arisen? It is because when the Science Policy Resolution was presented, the common man immediately came into the picture. The common man appreciates science through the material benefits science has provided through its application or more appropriately through technology, which is the basis of industrialisation and consequently of economic growth. Science can show the possibility of something to happen, it cannot by itself make it happen It needs technology to achieve what may be indicated as possible. Science produces knowledge, technology helps to produce wealth. Science indicated the great possibility of man landing on the moon, it is technology that made it possible This makes one immediately appreciate the need to differentiate between the two Eminence in science need not necessarily mean better or more productive technology. Also, while science is international, knowing no boundaries, technology is not Science is intellectual but technology is commercial. While scientific knowledge is shared throughout the world, technological knowledge is not freely shared It is shared on certain considerations While advancement in science is based on collaboration, advancement of technology has its root in competition. There is competition in technology not only between countries but between industrial establishments in the same country. No firm shares its technological knowledge of method of production or know-how or design with another company operating in the same field without certain adjustments.

To the scientist, science is an end, a great intellectual end, a curiosity satisfying end. But in the twentieth century, technology is becoming more and more science-based, it has also become a powerful tool of economic growth Economic growth is important for all countries, but for the less developed nations like ours with a large section of people suffering from wants of basic needs of life, it is the first priority—it is everything. It will be well for the scientific community to appreciate that the interest of the Government and of the people in the increasing support which science is receiving is more for the material benefits that flow from science rather than for science itself. For the people science is more important as a means to prosperity rather than an end itself. If it was only for science as an end, as a creative activity, Government's role would have best been of a indulgent patron to provide scientists the facilities for doing science, just as Government patronize poetry, music, drama and other arts. The need for a science policy has arisen because of science becoming the base of technology and as such becoming for the people more important as a means rather than an end It means that laying down science policy is actually laying down technological policy

I said in the Presidential address to the Indian Science Congress in 1968 that India needs a technological policy statement I wish to reiterate it on this occasion We have an Industrial Policy Statement and we have a Science Policy Statement. Both these statements refer to national development in terms of industrialisation in the first case and to the importance of science in the second. It is my view that we should have a carefully worked out technological policy statement to provide a strong link between the other two policies. It will provide economic content to the science policy, it will spell out what we want to achieve through science What is the national goal for all our activities in the field of science and technology? Why are we making substantial investments in science and technology? These questions will immediately set in motion a meaningful dialogue between educationists, scientists, technologists, engineers, economists, planners and administrators. The present discussions on science policy do not bring into picture economists, manufacturers, etc Similarly the Industrial Policy does not bring scientists within its orbit. It is only a technological policy which will bring all of them together into an effective and collaborative endeavour It is not merely a matter of how much support science should get, no doubt it is important with the increasing sophistication factor of science. Scientists will always ask for more support and will be happy to receive it but the question is. Support for what? and how efficiently and judiciously the support is made use of? The National Institute has a great role to play in this and I request Fellowship to take more interest in this matter

I should like to thank all the officers of the National Institute for giving their time for the work of the Institute and the entire Fellowship for their co-operation and understanding without which I would not have been able to discharge my duties. I should express personal appreciation of the work the office staff of the Institute led by Dr S Mull have put in through the year

NATURE AND SCOPE OF A SCIENCE ACADEMY

ATMA RAM

(delivered at Bangalore, 1971)

I deem it an honour and a privilege to have been the President of the Indian National Science Academy during the last two years. I will cherish the Presidentship of the Academy as the highest distinction that has been bestowed upon me in my scientific career. As the outgoing President, I think it is incumbent on me to make an assessment of the affairs of the Academy during my tenure, and in doing so to refer to some of the contemporary problems of science in India as they appear to me.

As Fellows of the Academy are aware, there was a distinctive change in the working of the Academy during the tenure of my distinguished predecessor, Professor T R Seshadri. The Academy became increasingly aware of its role, responsibilities and potentialities. Earlier, the Academy was perhaps more concerned with preserving its scientific chastity, than getting involved in functions which would bring the Academy face to face with various social problems and Governmental responsibilities in the field of science. The new interfaces which are developing between the Academy and the Society on the one hand and between the Academy and Government on the other are posing fresh problems. To what extent these problems would be faced by the Academy as an independent body of scientists, uninfluenced by considerations other than scientific, remains to be seen.

One aspect which is uppermost in my mind is the danger of a conflict of interests, which Fellows may have to face. I may refer, for example, to the fact that my views expressed as a scientist in capacities which have nothing to do with my Governmental responsibilities have been used to interpret as if I was going against the policies of the Government. Fellows may be aware of the current debate in the United States of America about the nomination of Dr Glenn T Seaborg, a Nobel Laureate, Chairman of the US Atomic Energy Commission, for the Presidentship of the American Association for the Advancement of Science. It is being argued by some people whether Dr Seaborg, holding a high Governmental responsibility, should be President of the AAAS. A problem like this may not be of immediate relevance in our country, but it could arise. It is important and essential for scientists, who are Fellows of the Academy, to take a truly scientific point of view of problems regardless of whether they come from the academic world, Government or industry. I hope nothing will be done to curb the freedom of scientists to give expression to their scientific viewpoints as Fellows of the Academy, when the Academy is called upon to render independent advice to Government or express opinions of concern to Government and industry. Should anything happen to the contrary both the Government and the scientific community will stand to lose.

During my tenure, I have attempted to develop, to the best of my ability, the activities of the Academy to further its objectives. In my case, unlike that of my predecessor, the possibility of conflict of interests coming in the way of my effective functioning was very real simply because of the fact of my shouldering simultaneously a Governmental responsibility. It is for the Fellows to judge to what extent I have served the interests of the Academy. Let me begin by referring to the change in the name of the Academy from the "National Institute of Sciences of India" to the "Indian National Science Academy". In my view, this change is for the better and is indicative of the wider responsibilities of the Academy As in other countries where there are science academies, in India also the Indian National Science Academy has become the national adhering body for the International Council of Scientific Unions and its affiliated Unions. In the 19 National Committees constituted by INSA with a total membership of about 170 scientists, more than half are from outside the Fellowship of the Academy. Out of 47 delegates sent abroad by the Academy in 1970 to attend international conferences, only 11 were Fellows of the Academy.

Another significant development was in the field of international relations. This activity is growing and may become, in the years to come, very important not only from the point of view of the Academy but from the national point of view as well. We have now collaborative arrangement with the Academy of Sciences of USSR. We are also developing relations with the National Science Academy, USA and the Royal Society of London. The collaborative projects initiated with the Academy of Sciences of USSR are making steady progress. This year, we propose to have a joint discussion with the National Academy of Sciences of the United States on problems of environment. We are likely to have more of joint symposia and projects in the not-too-distant future.

In October last, as your President, I led a delegation to USSR to attend the meeting of the Joint Indo-USSR Committee on scientific collaboration and to discuss with the Academy the whole field of our co-operation I also visited London and along with Prof Mahalanobis had discussions with Lord Blackett at the Royal Society and other officers of the Society on the possibilities of co-operation with our Academy. As a result of this discussion, a get-together would be organized in Delhi in coming March and we expect Lord Blackett and an important group of Fellows of the Royal Society to visit us.

During the last two years, we have taken steps to organise some schemes of basic importance in a number of areas of science, several of them not adequately covered by the existing Governmental and other agencies Among the 30 and odd projects under this scheme, the expedition for the study of Arabian Sea islands, the investigation of the movement of Rajasthan desert and the investigation of the flash floods in river Alakananda show the importance attached by the Academy to scientific investigations of special and topical interest

I am also glad to report that our efforts to bring the CSIR and the Academy together for the purpose of joint publication of scientific periodicals has proved to be successful. We have also started a new journal, the Indian Journal of Pure and Applied Mathematics, as a quarterly and it has been very well received

If the Academy has to make itself felt in a large country like India, it is necessary to organise local Chapters at important centres. A decision to this effect has been taken and we have organised local Chapters in cities like Calcutta, Bombay, Madras, Bangalore, Poona, Hyderabad, Lucknow and Chandigarh. At least in each quarter one topic for discussion by each Chapter should be a problem selected by the Council of the Academy I look forward to the day when our local Chapters will become focal points for young scientists living and working in these geographical areas to meet and discuss on current scientific and also socio-economic problems which have distinctive scientific content. Among the topics which have been selected for discussion in the immediate future are problems of environment and of research and development relevant to the needs of small and medium scale industries. In addition to sponsoring the Symposia and Seminars the Academy had arranged in

Delhi, during the last two years, discussions on topics like popularisation of science, emoluments of scientists, impact of science and technology on human rights and development of technology in Japan.

A National Science Academy is very different from a professional association or a scientific society. Professional associations are generally open to all those who are engaged in the pursuit of a particular profession, subject only to the limitations of qualifications, experience and sometimes, perhaps, residence. A professional association can have different classes of membership including student membership. They do sometimes conduct examinations and recognise qualifications from the point of view of practising the profession A scientific society may be open to all those interested in a branch of science and who possess a requisite minimum proficiency. A National Science Academy on the other hand consists of scientists elected for outstanding contributions in their respective fields of work. The system of election to the Indian National Science Academy is very similar to that adopted by the Royal Society of London, the National Academy of Sciences of the United States and the Academy of Sciences, USSR and similar scientific Academies in other parts of the world. It should not be correct to judge the representative character of a National Science Academy by the ordinary methods of democratic criteria Membership of such Academies is generally confined to a small fraction of scientists in a country. The main criterion of judgment should be whether the Academy consists of people who are distinguished scientists of the country. The fact that some persons holding positions of authority in government institutions or elsewhere, have not been elected to the Fellowship does not and cannot in any way lessen the status or the value of the views of the Academy. This is so in all countries where such Academies function. We have to be on guard that election to the Academy is not influenced by considerations other than scientific. The Academy has been making and will continue to make every effort to ensure that persons deserving election are not left out.

The Indian National Science Academy started with 124 Foundation Fellows in 1935 Today, it has a membership of 355. An analysis of the specialisation of present Fellowship is—Mathematics 46, Physics 60; Chemistry 53; Geology 28; Engineering & Technology 31; Botany 47, Zoology 36; Physiology and Biochemistry 28, Medical and Veterinary Sciences 25, Social Science 1. We have been adding 10 or 15 scientists every year to the Fellowship While claiming no perfection, I should think that the method adopted by the Academy in the election of Fellows is as good as that practised by any other similar Academy in the world. The Academy is fairly representative of the scientific community as it has developed in the country. In future, the composition may vary; it is bound to vary. I do foresee more technologists in the Fellowship.

The extent to which an Academy like ours assumes responsibilities or is entrusted with responsibilities may vary from country to country, but in most cases, they derive large part of their finances from Government. In addition to donations from Foundations and individuals, the Royal Society receives a Parliamentary grant-in-aid of about a million pounds for supporting scientific research, scientific publications, international collaboration, scientific congress, etc. Similarly, the National Academy of Sciences in USA, derives finances to the tune of about 40 million dollars per annum from the Federal Government. However, they operate not as an arm of the Government. They are quite free to function as an independent Academy and express scientific opinion on national and international problems. The Academy of Sciences of USSR, besides being a scientific academy, is also a whole-time agency of the Government and like a Research Council controls and manages a large number of research laboratories.

An Academy has the very important role of providing independent counsel to Government, but it is entirely for the Government to accept such advice or not It is nevertheless essential for the proper development of science and technology that Academies express scientific opinion and advise Governments fearlessly The advice should not only be available to Government but wherever possible its views should be publicised for general information of and discussion by the public

In the functioning of the Academy, it is but proper that it should have consultations not only within its own Fellowship but also with scientists who may not be Fellows of the Academy While election to the Fellowship of the Academy is based on certain criteria, it does not preclude expertise and specialised knowledge among scientists who may not be Fellows and who ought to be consulted by the Academy. I am glad that our Academy has taken a broad view of its functions and has unhesitatingly made use of such knowledge outside its Fellowship. The figures which I have quoted earlier about National Committees and delegations amply substantiate the point.

Let me now come to a discussion on some of the current problems of Indian science I do not know to what extent the Academy would like to get itself involved in these problems. While I have no specific suggestions to make in regard to the degree of such involvement, I feel that the Academy has to be deeply conscious of what is going on around it, take stock of the situation and perhaps get actively interested in these problems. The one that immediately comes to my mind is the excessive involvement, and if I may say so, preoccupation of a number of people in debates and discussions on the organizational aspects of science in India. To say that I am concerned would be putting it very mildly, in some respects, some of the things which are happening deeply perturb me. People and organizations who have not had much to do with science are often giving expression to opinions and suggesting solutions to various scientific and organizational problems of science with a vehemence and certainty which is amazing. We are a democratic country Everybody has a right to express opinion freely on any matter But we seem to be losing the cultural and intellectual discipline which should prevent one from expressing strong and categorical views on matters which essentially need long period involvement and practical experience. Scientific research is one such field

Recently, there was a conference of scientists, technologists and educationists held in Delhi, mainly to discuss the progress in the implementation of the Scientific Policy Resolution of 1958 and to suggest measures for future action in pursuance of this Resolution. The 150 or so participants were said to represent a cross-section of those concerned and were picked up at random. Can or should randomness be a strong point for a conference charged with great and special responsibility?

In her inaugural address to the conference, which was remarkable for both clarity and insight, the Prime Minister posed a number of important questions for the conference to tackle She asked the conference to identify the factors responsible for incommensurate return from the quantitative expansion of scientific research and education What were the basic problems of high priority? She asked the conference to formulate specific recommendations for action, such as a series of research and development programmes related to specific socio-economic goals; the goals to be achieved in terms of enhanced production capacity and what should be the scientific and technological means required to achieve these goals. The Prime Minister significantly remarked:

> "A great deal could also be done in the formulation of joint research projects between groups in Government laboratories and universities and by joint appointments of scientists between universities and laboratories I know of many seminars and conferences, but I do not know if any really serious programme has yet been presented."

The Prime Minister's doubt seems to have been justified. To my knowledge, after three days of deliberations, the conference does not seem to have tackled these important issues No new policy for science and technology for the next two decades appears to have been formulated No priorities seem to have been earmarked It more or less turned into a discussion on the administrative and allied matters of scientific organisations in India. One of the key papers discussed was a report entitled "Management of Scientific Research". The report mainly concerned the CSIR and the National laboratories It is difficult to appreciate the large effort put in merely to discuss the administrative and organisational affairs of a single scientific agency in the name of considering scientific policy or the general questions of management of science in India. There is nothing against discussing an organisation or its management. Is it, however, necessary to do it in this manner? Since it could not be explicitly stated that the CSIR was at the back of it all, the discussions tended to be somewhat laboured Preoccupation mostly with personal problems, resulted in the neglect of basic questions to which the Prime Minister had drawn pointed attention.

An important point and a substantive lesson has been missed. Since the adoption of the Scientific Policy Resolution in 1958, through the powerful advocacy of Pandit Jawaharlal Nehru, Government support to research and development, which was about Rs. 25·00 crores in 1958, has increased to over Rs. 150·00 crores in 1969-70. The number of universities and research laboratories has grown considerably, so also the number of scientists and engineers. The COST report has made out that the scientific manpower of India is now comparable with that of countries like the UK, France and Germany and substantially higher than that of countries like Canada, Sweden and Italy. Let us ponder over this fact for a while Either the data are not correct or, if they are right, there is something fundamentally wrong with us, scientists and engineers, in that we have not been able to make the impact which our counterparts have been able to make in the countries referred to; does this mean that our scientists and engineers have inferior equipment to be effective? May be the definition of scientists used for statistical purpose is not appropriate. When we talk of scientists, we have to be careful as to whom we have in mind

I have a feeling that lately we have been building up a new class of scientists in our country who, perhaps, never worked in a laboratory outside their degree career. If I may say so, a new science bourgeois class of scientists is growing, who are, without working for any length of time at the bench, assuming great importance in our scientific organisations Since I came to Delhi about four and a half years ago from the laboratory situated far away from Delhi, I have witnessed the growing importance of this new scientific class. The immediate effect of this development is that many bright young men and women of India are beginning to feel that to obtain recognition in science it is not necessary to put in hard work at the laboratory bench but perhaps drift into new and attractive realms which make them important and influential in the right places. One often hears about the need of proper atmosphere for scientific research. In the face of what I have described, can one expect the right atmosphere to develop?

To know the technological strength of a nation, one has to view the material output of her industry; the scientific strength of a nation on the other hand lies in the logic and philosophy which guide her men of science and their contribution. If the logic and philosophy are such as to take the scientists away from the work bench into areas of white-collar work, I do not see the value of the numbers, whether they compare with UK, France or Germany. The very fact that the scientific strength, as different from numbers, of India is nowhere compared to that of UK, France or Germany substantially proves my point that the logic and philosophy of numbers leaves much to be desired The most disturbing feature, I believe, is the growth of the new bourgeois class I have referred to

But the most curious aspect of the conference held under the auspices of COST related to COST itself It, more or less, conceded the inadequacy of COST. Therefore, a suggestion was made that there should be a new national apex body for science policy, COST not being adequate. There existed before COST the Scientific Advisory Committee to the Cabinet. After several years of work, it was felt that SACC was inadequate and was replaced by COST. Now, after two years, the conference suggests a new body. I do not see what guarantee is there that the new apex body will be a greater success Have we ever looked carefully into the matter why the former SACC and the present COST are considered to be inadequate? Various reasons have been adduced These, in my view, are rather superficial. I consider that if these two bodies have been inadequate, it is because they hardly discussed science, they discussed mostly problems of administration and organisation. Another reason may be that they had too few independent scientists unconnected with Governmental agencies.

Science and scientific institutions can be organised and managed in many different ways and there is no ideal solution applicable to all institutions at all times and under all conditions. As one of the participants in the Conference remarked "organisational gimmicks cannot carry one very far". Ultimately, whether a scientific institution succeeds or not depends entirely on the scientists working in it and the leadership. The scientific strength not only of a nation but even of an institution is dependent upon the logic and philosophy which guide the scientists working in it The basic problem is to develop a strong scientific community which takes pride in itself, has appropriate ethics, respect for quality and comraderie within itself and with the rest of the society I have mentioned this several times before and I wish to repeat here once again that there is no substitute to good scientific work at the bench. It is the work of dedicated scientists which will create an impact on the solution of our problem of economic growth and raise the edifice of science in India and not all this talk of management Not all the sophisticated equipment, modern services, management and administrative niceties will bring an atmosphere of science and temper of science if the dedication to scientific work is lacking Our young scientists should not get away with any impression that there is some short cut to success. It is the sacred duty of our senior scientists to spread this message I feel greatly distressed that the tremendous preoccupation with organisational aspects of science is obscuring our sight from the substantive aspect of scientific progress which is not organisation but science itself

I am sorry if I have given you a heavy dose of cynicism Perhaps, this might entitle me to be classed among the intellectuals I strongly feel that the Indian National Science Academy should get agitated over some of the issues which I have raised. Perhaps, there are much deeper and larger issues involved It is only an independent Science Academy which claims to be the premier organisation in the country and whose charter includes that it will promote and safeguard the interest of scientists that can organize the right opinion among scientists. The Academy must, I believe, express itself clearly and forcefully. If the Academy will leave a vacuum, others will fill it.

Professor Bagepalli Ramachandrachar Seshachar, FNA*

(Elected to the Fellowship, 1953; President 1971-72)

Professor B R Seshachar, Honorary Associate Member, Centre for Theoretical Studies, Indian Institute of Science, Bangalore was born on January 9, 1908. He received his B Sc. degree from University of Madras in 1940 specializing in cell biology and protozoology. Professor Seshachar was the Head, Department of Zoology, University of Mysore and Delhi and Professor Emeritus at University of Delhi before joining his present assignment He is a Fellow of the Indian Academy of Sciences, Bangalore; Zoological Society, India and London; American Society of Protozoologists; International Society for Cell Biology, Society Sigma Xi and the recipient of S L Hora Medal (INSA) in 1965.

Professor Seshachar's earlier work has been concerned with the cytology and development of germ cells of the Gymnophiona, a group of highly interesting amphibia, of restricted distribution but of great phylogenetic importance. The occurrence of the homologue of the Bidder's organ in these animals has been reported for the first time and is a finding of the greatest interest

Since 1946, he has been concerned largely with the cytology, cytochemistry and differentiation in the Ciliate Protozoa He studied the cytochemistry of the macronucleus and micronucleus with a view to understand their relationship and the nature of their differentiation. He was the first to employ photometric methods for the determination of their DNA content and establish a relationship between the amount of DNA and ploidy. The macronucleus of the ciliate was thus shown to be highly polyploid, containing several hundred times more DNA than the micronucleus, from which it is differentiated More recently, he has shown that the macronucleus contains greatly elongated chromosomal filaments Electron microscope studies have also been made, which indicate that the macronuclear chromosomes are amongst the most unique found in any animal.

**Address*: 50, 10th Main Road, Malleswaram, Bangalore 560 055.

LIFE SCIENCES AND NATIONAL DEVELOPMENT

B R SESHACHAR

(delivered at Calcutta, January 1972)

I do not have to apologise for borrowing, for my address here, the title which was the main theme for the India-US Binational Conference on Life Sciences held in June last year. As a biologist of many years standing, and as one who had some hand in organizing the Binational Conference, I might reasonably be expected to have developed, over these years, some ideas of teaching and research in the Life Sciences in the country, and their bearing on national development I don't claim to be alone in this I am sure, many of you, Fellows of the Academy, scientists and biologists particularly, are quite well acquainted with problems relating to life sciences and national development, and to such of you, the general observations I am going to make may appear nothing new At the same time, with new emphasis given to life sciences all over the world and the promise held out that the recent break-throughs in biology herald a new thinking in the relationship between science and the society of man, it might not appear irrelevant to talk about the state of teaching and research in life sciences in this country and the directions in which it is moving. For, it is important to understand, after several decades of teaching and research in the life sciences, for that matter in all sciences, what we have achieved and plan for what we wish to do in the coming decade or two. When I say this, I do not wish to give you the impression that I am going to engage myself, in the half hour or so that is at my disposal, in an extensive review of the state of biology in the country and prescribe measures for the future. But I do want to dwell, however briefly, on some aspects of teaching and research in the Life Sciences and hope that they might receive the consideration of planners of science in our universities, research institutes, and other laboratories, and most importantly of the scientists themselves.

Teaching in the Life Sciences in any organized manner in our universities began some time around the beginning of this century and has always been done as discrete disciplines of Botany and Zoology, on the pattern that these obtained in Britain, whose scientists not only designed our courses of study in those early years but also participated in teaching these courses Many of the older scientists here will recall the role which Universities like Allahabad, Lucknow, Madras and the old Punjab played in organizing Life Science departments They will also remember the pioneering contribution the national surveys made—the Zoological and Botanical Surveys—which were largely manned by British Scientists, some of them highly distinguished. Soon after, the Indian Science Congress came into being and acted as a forum for discussion of research findings and discoveries made in the University Laboratories and the Surveys.

Largely, this early work in the Life Sciences—both Teaching and Research—was patterned after the system obtaining in Britain, and concerned itself with Taxonomy, Geographical distribution, Morphology and Structure of a large variety of animals and plants in our sub-continent. The result was, among other things, the compilation of our Fauna and Flora which constitutes even today a most valuable addition to our knowledge of the natural history of India and of Asia.

However, soon after the 2nd World War, with the new orientation given to teaching and research in all branches of sciences, including the Life Sciences, with increase in the number of universities in the country, and with the coming into being of the Atomic Energy Department, the Council of Scientific and Industrial Research, Agricultural Research, Medical Research and more recently of the Agricultural Universities in the country, biological sciences acquired a new importance and both teaching and research in the Life Sciences became not only diversified but also intensified Applications of biology to agriculture, medicine, fisheries were recognized even more clearly than before and with many more opportunities afforded to our young men for training abroad, especially in the United States, newer disciplines like Cytology, Genetics, Ecology, Microbiology, were introduced in addition to such useful disciplines like Entomology, Fishery Biology, Helminthology We have today in almost all our universities in the country post-graduate courses in Botany and Zoology and in several specialized universities and institutions, special disciplines like Plant Pathology, Plant and Animal Breeding, Genetics, Agricultural Entomology, Nematology, Fishery Biology, Forest Biology, are being developed and research in them is being done. The recognition that for any meaningful understanding and explanation of biological phenomena, competence in chemistry, physics and statistics is important, is relatively new, and though in India it has been realized only recently, an admission of this relevance has not been unequivocal; but it is being increasingly appreciated that functional aspects of animals and plants cannot be studied or comprehended without an adequate knowledge of biochemistry and chemistry of natural systems.

With all this, our teaching and research in the life sciences remain weak and I should like to spend some time discussing this.

It is admitted that any process of strengthening science and any efforts towards modernizing it must begin in our educational institutions—not only in the universities and colleges, but in our schools as well. No attempt to improve the quality or content of our Life Science programme will succeed unless we start the improvement in our teaching institutions It is futile to attempt to build sophisticated high-level research organizations on the insecure and inadequate base of low-level teaching and training It is admitted that our active scientists, in our national laboratories, ICAR institutes and Atomic Energy establishments, are by and large those who have received their advanced, even earlier, training in the universities in other countries and even today, long after post-graduate teaching and research in the sciences is established in our universities, the country has come to rely on scientists who have had this training abroad for manning the laboratories, under different agencies. When I say this, I should not give you an impression of my being chauvinistic I am merely expressing my concern at the inadequacies in our universities to meet the requirements of modern research, be it mission-oriented, applied research, or fundamental research directed towards making new discoveries in knowledge.

One of the important lacunae, therefore, in our programmes of Life Sciences is the weakness in their teaching and this largely concerns the universities, colleges, and to a certain extent, our schools also This weakness is due to two causes One obvious cause, relating primarily to the school level, but applicable to the University level also, is the large number of students flocking to our educational institutions and our inability to match this student input with other inputs necessary to make for effective or even meaningful training. Every year, our student enrolment is growing around 10% (or more in some fields) and to make provision for other requisites to take care of these young people and teach them has become an impossible task. Even some progressive universities find their resources strained to the very limit and where, as in the sciences, and particularly in the Life Sciences, the requirements of much needed equipment, library facilities and as it often happens, even space, are not adequately or even modestly met, the quality of training itself should suffer. That this constraint should be imposed on educational institutions where future generations of scientists are trained, is tragic and should necessarily affect the quality of research itself. I do grant that in a country like ours where the demands for higher education on the part of the people are incessant and it is believed that higher education is the right of all and not the privilege of a few, this spectacle of spreading scarce resources over a large number of institutions and people, is a common one but it is my belief that even so, some selectivity, at least in so far as the sciences are concerned, would seem inevitable if we wish to avoid the situation created by Engineering Education, for example I am sometimes appalled at the thought that very soon we shall have hundreds of Physics and Chemistry M Sc s clamouring for jobs in the country The situation in the Life Science is not yet as bad but the compulsions of society are irresistible and the officers of the University Grants Commission are for ever going around the country, accompanied by 'experts', prevailing upon University departments to increase their intake at the M Sc and Ph D levels, throwing at them blandishment of higher grants for equipment (which in any case is not available or difficult to obtain) or additions to faculty positions None of these are totally relevant, because what in the final analysis relevant is the manner in which these people find themselves employed. The lesson which Engineering has offered us should not under any circumstances be forgotten.

While the large number of students entering our universities, colleges and schools constitute a factor in the enfeeblement of our training programmes, there is another reason for this. This concerns the quality of such training and the components of the training programme. The Life Sciences departments in our universities are built on the traditional pattern of separate botany and zoology, and wherever they are present, the biochemistry and microbiology departments, with little or no interaction among them. Certainly there is even less interaction between these biology departments and the physics, chemistry and mathematics departments in the university. This separation of Life Science teaching and research into two or more isolated departments and their functioning with no reaction with the physics and chemistry departments particularly, have led to a lack of integrated teaching of biology and have prevented the utilisation of methods which physics and chemistry have offered in the understanding of biological phenomena While the arrangement where Botany and Zoology departments in a university were discrete and often incommunicado is a historical fact, with the acceptance that they constitute study of living systems, is no justification for their continued existence as separate departments That many of them have been in existence for many years and that any attempt to integrate them now is sure to cause traumatic disturbances are not arguments for the prepetuation of a system which is manifestly disadvantageous to the students whose interest alone should ultimately prevail Again that our students in the Life Science departments are deprived of competence in physics, chemistry and mathematics which are so vital to the understanding, analysis and solution of biological phenomena, is a situation which should call for immediate redress.

These two causes are, to my mind, contributive to the weakness in our Life Sciences programmes in the country. An attempt to remedy them in the form of affording encouragement to universities—especially new universities to start integrated Life Sciences courses has not been successful. For one thing, new universities, especially in the States, are beset not only with poor resources position, but also poor thinking and the two or three universities where this was attempted, have really made no striking head-way. It is necessary that some of our older universities should set a model and get integration started, academically, if not organizationally No vested interest should stand in the way of a measure which everyone of us declares as the correct one, but none of us has the courage to put through. The University Grants Commission can play a forceful role in this regard. It should declare that to qualify for grants from it for development and maintenance, clear evidence of co-ordinated courses not only between Botany and Zoology departments, but also with Chemistry and Physics departments should be available. This is not easy to achieve, for the thinking of fifty years or more cannot be changed in a short time, but my sorrow is, we haven't even got started on these lines and the longer we delay, the greater the time lag for the achievement of this objective

The Binational Conference in Bangalore dealt with this subject and recommended the integrative approach to teaching biology but, I am afraid, it was not forthright or forceful enough There was, I believe, a clear consensus on this subject but the Conference, consisting as it did, of Professors of Botany, Zoology, Microbiology and Biochemistry departments, felt constrained to recommend halting measures for correcting a situation which everyone felt was unsatisfactory They knew that even in Britain it was being rapidly remedied I should make it clear that this is the first essential step needed for modernizing Life Sciences teaching in our universities and would go to the extent of saying that scientists should not be permitted to thwart attempts to this measure of progress, and that if they happen not to agree to a measure of integration, *albeit* gradual and progressive, the University authorities should prevail upon them to do so. For, it is my belief that if the scientists in the existing Botany and Zoology departments display hesitancy and reluctance to such an integration, it is not because they are not convinced of the usefulness of such a measure but largely because they are apprehensive of not only the consequences of such integration to their own personal positions, but are unsure of the manner in which such an integration can be effected with the least possible trauma. I believe an understanding and appreciative administration should be able to allay these fears and restore to the teaching of biological sciences the prestige and the usefulness that rightly belong to it, and confer a modernity to it

The understanding that a sound knowledge of physics and chemistry and mathematics especially statistics, is not only useful but also highly necessary for comprehending modern biology has brought in its wake some complications In their anxiety to be modern and not to be left behind, some of our biologists, unmistakably traditional in their training, have picked up along their way in an *adhoc* manner terms and ideas which are often halfbaked and shallow Physics and Chemistry are important disciplines and one cannot pick up competence in them in a casual manner I am often amused at the way in which, after a six month or year's work in a laboratory abroad, using some enzymes and biochemicals, the botanist or zoologist claims to be a biochemist! I am equally amazed that a person who used an electron microscope for some of his studies, or a Scintillation Counter or some integrated circuits, poses as a biophysicist! We should learn to treat physics and chemistry and biochemistry, with greater respect, just as we biologists should learn how to respect ourselves a little more. It is easy to effect curriculum change, to introduce into our undergraduate and post-graduate courses topics which lend prestige and confer on them an appearance of prestige. It is far more difficult to find the much needed inputs for effectively teaching these courses and training our students to do research in these topics. Of these inputs, trained teachers are the most important, teachers who are able to inspire their students and introduce them to the new biology that is coming up in many of the universities in the world.

One of the subjects to which the Binational Conference gave a great deal of thought and attention was the content and programme of undergraduate studies in the Life Sciences The conference felt that the 1st degree, which in many universities in our country in the B Sc degree, should be a broad-based general-purpose degree. Recognising that to the large majority of the people, this is the terminal stage of their university education, the degree should help them become informed citizens For the rest, it should serve as a basis for professional science education and training in applied areas; and for those who will choose science as a career, either in teaching or research, should prepare them for post-graduate studies The Conference went on to emphasise the need for the inclusion of mathematics, physics, chemistry, humanities and social science, and even prescribed some general topics in the biology curriculum, both compulsory and elective. These are useful guidelines but I wish to go on and say that a radical change is needed at this level If it is true that the large majority of the people who obtain the B Sc. degree do not pursue higher studies in their discipline, if it is true that the courses they take should assist them primarily to prepare them for informed citizenship, then many of the things we are now teaching them at the B.Sc. level are not only unnecessary but utterly valueless. What value is it to him to know that the salivary glands of the cockroach consist of a pair of racemose glands, that each gland consists of two lobes, that there is a reservoir on each side and that there is a common salivary gland duct and other common reservoir duct etc., etc. Or, worse still, learn all about the structure and development of the star-fish which he is unlikely ever to see? Examples of this sort are in profusion and needless to say they make no impression and hardly ever help to make the young person science-minded. I would scrap all this completely irrelevent information and include in his biology curriculum topics of interest and usefulness to him I would prescribe for study at this stage topics of relevance to him as a human being and his relationship with other organisms and his environment. Some of these topics are given below:

Elementary facts relating to the working of the human body
Foods, food values, vitamins
Hormones, Physiology of reproduction
Hygiene, common infective and contagious diseases, their transmission, prevention, cure
The Environment, Population, Pollution.
Human Ecology
Basic facts of life, its origin, maintenance
Relationship between plants and animals
Energy utilization
Elementary biochemistry

A detailed list of topics could be drawn up and these would mainly cover the basic facts of life, its diversity and its maintenance This kind of change would demand great courage on the part of the universities It would also demand a new thinking on the part of teachers of Biology But I would like to say it would be received with enthusiasm by the students and ultimately would be in the interest of the nation itself

From this, I wish to pass on to the problem of special fields in Biology in which our scientists should lay emphasis, not only teaching but also research Here one naturally comes up with the question of the choice between basic work and applied work and preparation for them at the post-graduate level This is a question not restricted to Biology alone. It is the general belief that biology does not lend itself to application nearly as extensively as physics or chemistry. This may be true; but what it lacks in breadth, it acquires in depth. The impact of biology on agriculture, medicine, food, forestry, live-stock and so on is immense. The spectacular new break-throughs in agricultural production in all countries including our own are testimony to the application of basic knowledge in more than one branch of biology to food production. The whole matter of the newer understanding of the process of photosynthesis and its relation to multiple cropping is another such example. Again, in the field of medicine,—the etiology of of cancer, the genetics of human syndromes,—these are new areas of spectacular discovery which have an undeniable impact on man and his life Then again, the more recent emphasis on Ecology, the environment of plants, and the quality of the air, water and soils, is of great relevance to man But perhaps the most spectacular of them all is the scientific research in basic reproductive physiology which has led to newer understanding of the problems and processes of human reproduction and population control.

I specially wish to lay stress on the importance of bringing back in special focus, both in our teaching and research programmes, the problems of Man and his environment. There is to be sure, a certain vague awareness of human activity and its bearing on the quality of life,—industrialization, urbanization, extensive use of fertilizers, pesticides and other chemicals, nuclear power production, and so on,—but this awareness is largely confined to a few people. It is true also we are contemplating legislation on pollution of our water systems, and we are quite concerned about the changes brought to Man's biosphere, but a great deal more has to be done. We need to introduce elementary courses in Ecology in our schools. I believe the NCERT has drawn up one such course to be taught at the school level. It is necessary to strengthen Ecology teaching in our colleges and universities, not merely as a course in Biology but as an integrated interdisciplinary area of study, with Man as the centre of enquiry, involving in addition to Ecology, Meteorology, Oceanography, Population Studies, Sociology as well. For not only do we need to have full information regarding the changes caused to the environment by modern technology, agriculture and engineering, we also need to know how man reacts to and behaves in such changed environment. Basic studies are needed in several of these areas and none can provide them but our schools, universities and research institutions.

Let me given you one example. In one experiment carried on in the United States, over a period of sixty years, it was discovered that solar radiation, especially in the ultraviolet region, had decreased by about 16%, presumably due to atmospheric pollution, smog, and other types of air contamination. This loss of solar radiation should be expected to have very visible consequences, especially on photosynthesis

You will thus see the relevance of integrated teaching of biology, and the need to have sound knowledge of physics, chemistry, mathematics, astronomy, geography, meteorology and other allied subjects, in any attempt at teaching modern biology

Having said that, I should not be interpreted as implying that all higher training and research should be directed towards these problems of application to Man, augmentation of his resources or alleviation of his suffering. In any country, science should be designed to make man's life richer, fuller and more enjoyable (materially). But in a country like ours, where resources are scarce and problems of living for our people assume enormous proportions and appropriate the greater part of our attention, it is a must that much of our effort be directed towards meeting the requirements of man. But, I submit even in our country, there is a truism that without basic research, the fountain of creative thinking would dry up and man would be condemned to live in an uninteresting arid world, withal a world of plenty, and that for the spirit of inquiry to blossom, it is necessary to feed the flame of initiative and originality. However, it is not easy to define the limits between pure and applied biology and prescribe the inputs into each of them. By and large, basic research in the Life Sciences is now being done in the University departments while the several specialized institutes and laboratories under the different agencies are engaged in Fisheries, Forestry, Agricultural and Medical Entomology, Nematology, Marine Biology and so on.

The relationship between applied science and basic science, the attention and support which each one should receive in the country, the priorities that should be established and the place they hold in national development are all subjects which have been discussed in the past at more than one forum and I may not have much to contribute to the discussion. But I do want to spend a few minutes on the subject in relation to the life sciences.

I want the scientists here, and particularly the younger among them, to take note of the criticism that much of the basic research in biology in the country is repetitive and breaks no new ground. That a large country like ours with a scientific manpower equal to that of Britain, has not been able to produce more than one Nobel Laureate in the Sciences, is often, and quite seriously, cited as evidence of our scientists not taking their science seriously enough. That much smaller countries of Europe, with much less tradition of learning and literature, if not of science, have been able to attract world attention in science, is a matter which we in this country should take note of. We are a great nation. We have a long history of creative activity in several fields,—literature, art, music. Science and Scientific tradition might be something new, but a great people whose civilization and culture date back to several centuries before Christ and who even in the sciences like mathematics were pioneers in the past, should give a better account of themselves in the field of science. Creativity in the sciences is not easy. It first calls for brilliant minds; it also calls for these minds to be put to work. As a people, no one can say, we lack brilliance. The achievements of our people in the past can rank with those of any other people in the world and if, therefore, it has not been possible to turn these minds to creative science, it, I believe, is the fault of our society. I am not unmindful of the political structure of our country of the past few centuries and consequently the social structure of our people, which certainly have contributed to the weakening of our science but even so, I believe we could have done better. I am also not unmindful of the constraints under which our scientists have been working,—the lack of equipment, space, libraries and other things, including the absence in many fields of a critical size of a group of scientists,—but instances like those of Raman who worked with the most primitive equipment and whose working conditions were unimaginably difficult, should serve as shining examples. It might be trite, and many have pompously proclaimed it; but I do want to say that we have acquired a great deal of expensive equipment and apparatus in many of the laboratories, including a few university laboratories, but we have not fostered creative minds nearly as diligently. Ideas are important in creating new science and ideas rarely come from anywhere but human minds. Whether it is biology or physics or chemistry or particularly in fields like mathematics, and of course in the arts,—painting, music, poetry,—the importance of the individual has been lost sight of in our country and until and unless we recognize this importance and devote all our attention to nurture it, our science like several other fields of creative activity must remain infirm.

Almost any one can see evidence of it all the time. One has only to attend a symposium, a seminar or a conference that is held in this country; and especially in the areas of basic sciences and one can see how the majority of presentations made at these conferences relate to work that was done by the author (or his associates) in some laboratory outside our country or that is merely repetition of what is being done elsewhere. It is often no more than an extension of the person's Ph D thesis which was submitted there. I recently attended one such conference and saw that the greater number of papers related to work which blazed no new trail, developed no new concepts or presented no new ideas. It was an uninspiring experience Basic or fundamental science has been defined as science of discovery. It is born out of curiosity, and unless the mind moves out into the unknown and untracked, curious to find out what is in there, there will be no discovery,—no creation of new knowledge. Anything that does not do this, and is merely content to plough the old familiar furrow, with however new implements, progress is little and literally "no new ground is broken" Of course this is not given to all—this breaking of new ground It is a faculty of the best minds, of the greatest intellects. I cannot for a moment believe that we in this country do not have these minds, or these intellects, in a more abundant measure than would appear. I cannot for a moment believe that in other countries, there are more brilliant minds in larger numbers I must merely conclude that these do not by and large possess the adventure, the daring, the courage, to go out into the unknown and discover it. It is possible,—in fact I believe it is largely true,—that the environment in which these minds are placed, the milieu in which they are working in the country, is not such as to encourage young people to seek new things, put new ideas to work. This is tragic, for, to create new knowledge is no less the responsibility of those who provide adequate conditions for work than the young and brilliant minds that are engaged in scientific studies. If it is true that our young scientists are amongst the most brilliant, it should follow that they should create brilliant science. And anything that comes in the way hampers national development. The role of the creative scientist is not appreciated in this country nearly as well as it should be. There is often the impression that as long as we fill our laboratories and research institutes and University departments with men in enough numbers and provide them with equipment and other facilities, the progress of science is assured. Most of us see lengthy advertisements in our daily newspapers inviting applications for scores and sometimes, hundreds of positions in our prestigious agencies and organizations,—the AEE, the CSIR, the ICAR,—and so on. And like me, some of you might even have wondered what these large numbers of scientists do in these organisations I am sure they do something useful. However, that is assuring ourselves of quantity How do we assure ourselves of quality? What machinery do we have of detecting and identifying talent,—outstanding talent? And after such identification, have we the means by which this talent is made to develop? For, not only is it important that the selection of the most talented of our young scientists be assured, it is even more important that conditions be created for their talent to be developed fully and in the least possible time In fact, the latter is much more difficult, for, critical evaluation of creative potentialities of young scientists is not easy, and often hard work, diligence and wide knowledge pass for creativity, which they are not It is my belief that in regard to identification of talented people in our scientific establishments, evaluation of their creative ability, as well as affording conditions for the full development of their talent, we have done very little. And unless we do this quite urgently and determinedly, the fountain spring of creative activity in science will dry up and opportunities for growth of basic science will be altogether lost.

In this regard, the Academy can play a useful role and is prepared to do so. In fact in other countries, specially in the USSR, the Academy of Sciences is constantly alert and engaged in saving for the nation, the scientific talent of the country at all levels and the spectacular results the USSR has obtained, especially in Mathematics, are well known to us I believe it is necessary for us in this country too to pay attention to this aspect of our science development.

Under the plea of speaking of the present and future of teaching and research in the Life Sciences in this country, I have, I am afraid, talked about some general matters of Science and its development. I believe these have a relevance in any field of science, indeed in any field of human activity, and as one who has had some acquaintance with problems of science in this country, I felt perhaps I might utilize this opportunity to dwell on some of these matters.

SCIENCE AND THE UNIVERSITIES

B R SESHACHAR

(delivered at Chandigarh, 1973)

The President of the Academy is required, under the rules, to give, at the anniversary general meeting in January, an address bearing on a subject of his interest and one in which he has spent some time of study. This has been construed to mean, generally speaking, a subject or theme in which the President, as scientist, has been involved. In so far as I am concerned, I have, during the past year or two, paid little attention to my own scientific research, and consequent upon my retirement from the Delhi University, Zoology Department, in July 1971, have devoted all my time to matters related to the Academy. I have been named Emeritus Professor in the Delhi University after retirement, but this is merely honorific and hardly provides for any close involvement in the life of the University. While I have, as Emeritus Professor, the great distinction of being in the company of three distinguished scholars, one of whom was a past President of INSA and the other your future President, it means little more.

In consequence therefore, I have to deny myself the pleasure of speaking at this anniversary meeting on a technical subject.

I would, however, like to address you, on a subject of much wider interest, one in which I have spent a great deal of time. My connection with university teaching and research in two universities in the country for the past 47 years, my association with several scientific agencies here, and most importantly my Presidentship of the INSA have provided me with unique opportunities of examining the growth of science in the universities and entitle me to offer some comments on it. Recently, I have spoken about it at some forums in the country, even as some other eminent scientists have done, and written. I may therefore have little to add to what has been said but still I felt, a gathering of this competence and magnitude offers unique opportunities for making a personal survey of the situation that exists in the universities in the country, with the hope that we, who have gathered here, university scientists as well as others, may provide some thinking on the subject, if not solutions. For, wherever we may be working, whatever our position, the training in, and teaching of, science in the university as well as research in it have an impact on all sciences regardless of the agency where scientific research is being conducted. It is with that hope that I am speaking to you today.

Let me first begin by saying that the universities were the first organisations which sponsored and supported scientific research in India, and are even now the only ones where teaching and training in the sciences are being done. Some of our universities are over a 100 years old and three were started in 1857—Bombay, Calcutta, Madras. It was the university that provided the atmosphere for initiation of science in our young men and formed the basis for training scientists Of course, in those early days, no research worth the name was done and the universities were largely engaged in training administrators of all types and of all levels, to the extent that the British permitted us to do. The situation improved considerably at the turn of the century and young Indians not only distinguished themselves as members of the Civil Services but also felt that science as a career was open to many of them.

Several universities distinguished themselves then—Calcutta, Madras, Allahabad, Punjab, were some—and the science departments in these universities were named not only by distinguished British scientists, but by a number of young Indians. The starting of the Indian Science Congress in 1914 provided the necessary impetus and forum for scientists to announce results of their scientific work as well as discuss them with their colleagues.

Meanwhile, the universities grew; not only did the existing universities grow in size, but new universities were started too. We had only 5 universities at the turn of the century. We had 25 in 1947 when we attained independence. We have, I think, 90 today. 90 universities for a population of around 560 million people are not too many, but when universities are started with no other objective than to meet local pressures, when they serve no purpose but to confer degrees, when the enthusiasm with which they are started is not matched by the State Governments with a desire to provide facilities (or resources to do so), then, universities become not places where young men go for inspiration and learning, but burdens on society. This is exactly what has happened.

For, in our efforts and desire to please the local population, who have the strange concept that the location of a university in their town or area confers a prestige and dignity to it, universities have been started all over the country with no regard to the basic requirements to be met or to the necessary inputs to be provided. Almost all of them are nominally involved in teaching the sciences at both the undergraduate and post-graduate levels; in addition, these universities have encouraged colleges affiliated with them to do the same, with the result that, in many of them, post-graduate teaching is being done with little or no equipment, with few library and other facilities. There is no research going on in them, which is so important, especially for post-graduate teaching, and even the courses remain unchanged for many years. There is no interdisciplinary involvement to speak of, and the archaic administration permits little initiative or creativity.

The result has been that in many universities there has been hardly any breaking of new ground. The teachers are uninterested and often little qualified, the equipment is primitive and facilities limited, and it is difficult to expect, under the circumstances, that any advances in science can be made, at least in the experimental sciences.

No wonder therefore, the universities have come in for good deal of criticism. The Vice- Chancellors are blamed, the teachers are blamed, the students are blamed, the political parties are blamed and the University Grants Commission (which is supposed to oversee standards) is blamed. In fact, almost no one is spared. As if to endorse all this we see the spectacle of one university after another felled in the process. One Vice-Chancellor after another is sacrificed or is running away and, what is more significant, and perhaps happening for the first time in the country, no one is agreeing to be the Vice-Chancellor of even such prestigious Universities like Lucknow and Allahabad, which until recently were known all over the country as great seats of learning.

There is criticism too that, even apart from this, the levels of teaching and research have fallen in our universities, that standards in many of them are low, that far from being temples of learning they have now become centres of strife and indiscipline. There is fear that the great intellectual giants who inspired generations of students in the sciences, like Saha, Sahni, Mitra, Raman are gone and their place taken by persons whose intellectual calibre or devotion to science leaves much to be desired.

The picture that emerges from this analysis is a dismal one, and the only institutions in the country, devoted to the great mission of transmission of knowledge, lie in disarray, and not only science but all scholarship is at a discount in the country because the fountainhead of that knowledge, the universities, are suffering from neglect and decay.

It is a gloomy picture and bodes no good to the nation. One has only to pick up the morning newspaper to read distressing news, in one university or another in the country, of unrest, disorder, violence, police action and so on.

What is the reason for this situation, which has recently assumed unprecedented proportions? How do we correct it? And, specifically with the sciences, what are the measures we should adopt to retrieve it?

Unrest and disorder in the universities are not special to India. They seem to be a world-wide phenomenon. In Paris, in Harvard and Berkeley, in Warsaw or Rio di Janeiro, universities are in a ferment. It is clear that the reasons for these conflicts are not the same everywhere, and that while students all over the world share the common feature of being young, it would appear that in each case, a certain special element imparts urgency and importance, and provides the last vital cause for conflict. It may be overcrowding in one, Viet Nam in another, inadequacy of facilities in a third.

In India, it is a combination of several factors. The senseless and irrational proliferation of universities without providing them the basic needs is only one of them. The purposelessness of the courses in most universities, and the minimal value they provide for meeting the challenges of living is another. The alacrity with which political party conflicts get transferred to the universities is a third. The significant absence of both intellectual and administrative leadership is a fourth. But more important than all these, and the one which we seem to have neither provided for, nor sought to remedy, is the problem of numbers.

The enrolment in our universities has, during the past 20 years, registered such spectacular increase that it should be a matter of concern to our planners both at the Centre as well as in the States. In 1950-51 the total enrolment in our universities was of the order of 400,000, of which about 5% was post-graduates. In 1970-71, the total enrolment was more than 3 million, 8 times that in 1950 and the post-graduate enrolment had reached the spectacular figure of 163,000—18% of the total.

No university in the country has been able to step up its facilities to accommodate these huge enrolments. None has the courage to suggest alternative methods of meeting them.

That the unrest in the universities is primarily linked with pressure of numbers and that we cannot ever match these numbers with the needed facilities is not admitted by anyone That again the numbers of students in our universities are an inevitable consequence of our increasing population is even less appreciated When we are adding 12 to 15 million every year to our population, it is impossible to expect that our annual enrolment in our universities does not go up considerably, especially if, as we seem to feel, university education is the right of all and not the privilege of a few talented and motivated people. Just as we have not been able to provide the basic necessities for our people,—food, housing, clothing, medical and sanitary facilities and even protected drinking water, we have not been able to provide education, far less has it been possible to provide higher education.

The impact of population rise on our economic and social structure, in retardation and halting of our progress on almost all fronts is not a convenient subject for discussion at any forum. The destructive role of our rate of population increase on almost every sector of activity is a subject which our politicians mention only in passing; the relationship it bears to poverty, undernourishment, snarling and disruption of our services, and our economic and social backwardness is either not admitted or ignored because it is politically convenient to do so—that again this has a direct bearing on unrest, violence, disorder and that overcrowding, pressures of numbers, have strange and often unpredictable, little-known effects on man, are matters of concern to no one. Rustication of students, calling in the Police into campuses, appeasement of or firmness towards student groups, teacher groups etc. are temporary, ineffectual palliatives which merely postpone the inevitable day when we have to sit down and face the one inexorable reality—numbers

This according to me, is the crux of the problem. Some of us may deny it either because it is comfortable to do so or it is impossible to do anything about it, but this comfort is short-lived and soon events will pull our heads out of the sands in which we have buried them and we will be forced to adopt repressive measures whose severity will surprise the world.

The only way by which we could relieve pressure on our universities, as well as restore to them some semblance of standards, is to introduce some process of selection in our enrolment; but then this is politically abhorrent, however necessary it may be academically. The victims are the universities which either have to admit a large number of uninterested, poorly-equipped and ill-motivated students, or be subject to pressures from all sides—governments, parents, students and the public who believe that the universities are magic houses where all dross is turned to gold.

The time has come to delink the job opportunities in the country from the education which is supposed to equip them. The university degree has acquired in this country, the sanctity of a graven image, and it is pathetic to see thousands of our young men and women scurrying around to get no advantage from their university experience except a degree. From the present trends, it seems to me that we shall soon be giving a post-dated diploma or certificate to a student as soon as he joins the university.

The artificial position we have accorded to the university degree must be removed and learning and acquisition of skills restored to their rightful place. It is difficult to do so and in the context of present situation, none but the Government can do this. It is sure to cause a great deal of trauma, for the concept of a century cannot be erased in a day. But if we don't do this soon, the unrest in our educational institutions will spill over to our farms, to our industrial establishments, to our factories, to our mills and to our streets.

Already this is happening.

Also, it is necessary that the people themselves realize that it is not in their interest to send their children to the universities and that no special advantage is conferred by this. A reconciliation between Democracy and Quality must be reached and at the high levels of education we are talking about, it should be assured that Quality alone prevails. Some method of selection must be accepted at all levels. Preservation of quality is the only way in which preservation of higher education can be assured.

Much of today's criticism of the universities centres around the face that quality has been sacrificed at the altar of numbers In a forthright condemnation of the university system, Dr R Ramanna of the BARC deplored in a recent article published in the Illustrated Weekly of India, the tragic state of the universities and appealed for restoration to them of their rightful place as centres of learning, which they occupied even as recently as 30 years ago. While all academic values have suffered, science has suffered most consequent on the fact that quality science teaching and research depends to a large extent on additional inputs like equipment, library facilities, etc. The result has been that science research as a whole in the country has suffered, as Dr Ramanna observes. BARC's experience has been that most of the entrants into their organisation are so poorly equipped that special training facilities have to be provided by BARC after they are appointed. This is a commentary on our university science teaching, which deserves serious attention.

While numbers in the universities are a prime cause for fall of standards, especially in the sciences, there are other causes too. One is the utter neglect of the universities by government and the public. Education, and higher education particularly, is a State subject. The starting of new universities, support to them, maintenance of discipline in them, appointment of staff, are all in the purview of State Governments, either directly or through University Committees. Certainly the appointment of Vice-Chancellors is under their control. The University Grants Commission does exercise some supervision of standards and provides funds for development but the first is so marginal and the second often accounts for so little of the total budget of State universities, as to be of little consequence. Also, the States are jealous of their influence on the universities and hardly ever permit the incursion of an outside body to limit their hegemony. The universities have therefore become indigent status symbols rather than valuable and precious trusts. Neither the Education Ministry at the Centre nor the University Grants Commission has any control or effective voice in the governance of university affairs.

You will recall that some years ago, the then Central Minister of Education, Mr M C Chagla, aware of the fast deteriorating situation, attempted to suggest that Education be made a concurrent subject in our Constitution. I believe all but one State rejected this suggestion. That the States continue to keep the universities in penurious thralldom even with the possibility of assistance from the Centre is the tragic situation today in higher education. While it is not suggested that the Centre's participation or involvement in education in the States would deliver in into the haven of peace and progress, there would hopefully be more and greater opportunities for an exchange of ideas among the universities and a reduction of disparities in standards among them. For, among the most distressing features in the higher education landscape today is the appallingly low standards of them as well as the continual pressures on the relatively good ones to abandon all attempts to maintain whatever standards or academic reputation they have been able to build over the years. I am not sure if Government at the Central Ministry of Education is trying to revive this idea of Mr Chagla to make Education a concurrent subject; perhaps it may be worthwhile to make another attempt, for since 1963, it is admitted on all hands that, certainly university education has undergone much deterioration, and hopefully the States have come to realize now, which they did not do then, that the situation is so bad that if effective measures are not taken all hope is lost, and the young people in our country will roam about the streets as ignorant, restless nomads, jeopardizing the future of our nation.

In fact, this was foreseen long ago by Bhabha who, I believe, did make some attempts to bring about reform in our universities. Not obtaining a response from any university including his own, and clearly seeing the danger of whatever talent there was in the country being entirely submerged and smothered in the mediocrity and cussedness of our universities, he found he had no alternative but to concentrate on the building of one institute of excellence for the basic sciences and also fill the Atomic Research Centre with such scientific talent that he could pick up, and encourage it. While we may now feel that with his enormous organizing ability as well as colossal influence, he might have contributed to the strengthening of the universities in the country and thus provided the nation some assurance of standards in higher education, one can, in retrospect, appreciate his frustration and laud his attempts to salvage whatever was left of the desolution in university education. It is not claimed by the friends of the TIFR or AED that these organisations have retrieved higher education in the sciences. It was merely their hope that the pattern of administration obtaining there and the policies pursued, would provide some guidelines to the universities whose rules and regulations are so archaic, inflexible and out of tune with modern-day educational concepts that these are amongst the important hindrances for progress in them. Alas! this has not happened, and while some institutions have progressed, the universities, have by and large, been left behind. The obvious consequence of all this has been a further increase in the gap between a few progressive institutions in the country which have received support and the many university departments which, consequent on not only their numbers, but also their unprogressive policies, have become the poor cousins. A hierarchy has come to be built up, with some few institutions on the top enjoying affluence while the universities have come to occupy a lowly position of indigent, illequipped, poorly-endowed bodies with no prospects of improvement in any area of their activity except enrolment of larger and still larger number of students.

And yet, none but the universities can discharge the function of teaching and training, not only in science but for citizenship,—not the impressive laboratories of BARC, not the highly prestigious TIFR, not the many institutions under the CSIR or ICAR. None can claim to mould the minds of our youth or initiate methods and concepts of science as the universities can. None can participate in the transmission of knowledge. None can interpret the meaning of discipline or appreciate its value. None can take the message of science to our people. Without a strong base of science-mindedness we cannot hope to take our people into a scientific age.

This is our present tragedy. What is the remedy? How do we reconcile the growing numbers with the re-establishment of quality education, at least at the higher levels? How do we restore our universities the prestige and the intellectual power they enjoyed till recently and which universities enjoy in other advanced countries? How do we make them the potent instruments of change?

There are no easy answers to these questions And as elsewhere, it is easier to be critical than to suggest remedies Remedies there are, but they are hard ones, unpalatable politically, especially in a democracy like ours But they must be applied regardless of the trauma they are certain to cause. They must be applied by the Centre as well as by the States; they must be accepted by all and implemented without reservation. I outline some of these remedies:—

(1) No university should be started because of pressures. The contribution of a university should be preceded by adequate study, planning and organisational effort. The States should regard this as the first covenant.
(2) University education should be for the talented, for those who have the aptitude Some sort of selection should be introduced.
(3) The States, Centre and the University Grants Commission should give massive grants for improvement.
(4) Machinery should be set up immediately for curriculum development and modernization of courses.
(5) Universities must be required to pay increasing attention to the special problems of the area—the ecological, technological, sociological and economic problems in particular.
(6) Universities should cease to be mere conglomerations of disparate departments engaged in constant feuds for the appropriation of the meagre resources, but become the proving grounds for co-operative endeavour, intellectual interaction and emotional integration.
(7) Parochialism, regionalism, casteism and linguism should cease to have place in the universities. There should be mobility both among students as well as teachers.
(8) Antiquated rules and regulations for hiring staff should be done away with. Not only should

talented teachers be encouraged but, as in progressive countries, the universities should go out and look for them

(9) Some sort of machinery by which the Centre exercises, not control, but expresses appreciation of the problems of the universities should be set up fresh efforts for making Educaion a concurrent subject appear to be called for.

Do these measures appear utopian? They do, even to me. But in the modern age of science, utopia is a temporary concept Everything is attainable, everything feasible, provided we work for it

Ladies and Gentlemen, I fear you have been subjected to a rather tiresome account of the ills of the universities—perhaps too depressing. But I ask you, what is not depressing in our country? If we, not only in the Academy but also outside, both as a group of scientists and intellectuals, as well as individuals who are interested in the future of higher education in our country, give some thinking to these problems, I believe we should have, powerless as we are, the influence to alter the course of deterioration on which it would appear, university education is set.

After having said all this, I come to the formal part of my function, as outgoing President of the Academy.

It is a matter of great satisfaction to me that it was given to me to preside over the Academy during the past two years These two years have been most eventful and while I have not been able to do much for the Academy. the Academy has done much for me. It has brought me in close touch with a large number of scientists in this country and has enabled me to understand and appreciate the problems of science and scientists as never before. It has given me unequalled opportunities of providing, to the extent I could, encouragement to scientists. Coming at the end of a long period of teaching and research in my own field, it has opened windows on other areas of knowledge.

I cannot however say, I have been able to do all I wished to do, for the Academy. Two years ago, I felt I would be able to do many things. A period of two years is perhaps too short to achieve substantial gains, but it is my hope that during this period, I have made some contributions to its growth and development An institution such as this is much greater than any individual. But it is the individual contribution of every one of us that makes the institution greater and better. I do hope that those of you who, two years ago, placed so much faith in me as to elect me to this high and prestigious office in science in country, are not entirely disappointed. The Academy is a great body It has on its Fellowship all the well-known scientists in the country It is regarded all over the world as the spokesman of science in India It enjoys the greatest prestige in all countries from the United States to Australia to USSR to Britain It does not seek prestige except to accord prestige to scientists It does not seek influence except to mould our country as a modern nation.

I have had, during the two years of my tenure as President of the Academy, the unstinting and enthusiastic support of my colleagues and officers, the two Vice-Presidents, the two Secretaries, the Treasurer, the Foreign Secretary and the Editors of Publications To them and to the members of the Council should go the entire credit of whatever has been achieved or initiated during the past two years To most of us, the work of the Academy is a labour of love; we are actuated by no motive other than to serve it as best as we can, for we truly believe, by doing so, we serve science. Busy as these friends have been with their own responsibilities and duties, they have given their time amply and unstintingly. I am grateful to them.

Professor Daulat Singh Kothari, FNA*

(Elected to the Fellowship, 1936; President, 1973-74)

Professor D S Kothari, Emeritus Professor of Physics, University of Delhi and Chancellor, Jawahar Lal Nehru University, New Delhi was born on July 6, 1906 at Udaipur, Rajasthan He received his Ph.D. degree from University of Cambridge, UK in 1933. He is the former Professor of Delhi University (1934-73), Scientific Adviser to the Ministry of Defence (1948-61), Chairman, University Grants Commission (1961-73) and Chairman, Education Commission (1964-66). Professor Kothari is the recipient of Padma Vibhushan (1973) and Hon. Degree (Doctorate) from several Indian Universities (Delhi, Aligarh, Banaras, Roorkee, Rajasthan, Udaipur, Guru Nanak Dev Universities and others) and Leningrad University (USSR) and G. P. Chatterjee Award of Indian Science Congress (1981).

Professor Kothari's significant research achievements are: Theory of white dwarf stars and transport phenomena in degenerate electron gas; Ionization of matter by pressure ("cold body" cannot have radions larger than Jupiter); Application of partition theory of the numbers to statistical mechanics; Energy generation in cold (degenerate) proton gas; Formation of neutrons in degenerate star; Theory of fragmentation of large masses into stars.

**Address:* A-3 Chhatra Marg, Delhi University Campus, Delhi 110 007.

HUMAN IMPLICATIONS OF SCIENCE

D S Kothari

(delivered at Nagpur, 1974)

It is for me a great honour to address the anniversary meeting of the Academy. And all the more so when I think of the eminent men who in the past have addressed us.

Since independence, our country has been greatly concerned about promotion of science and technology, and its contribution to national development, economic, social and cultural. Science and technology are vital to development, but if this is to be harmonious, and not in the end self-defeating, the human implications of science and technology must ever receive our fullest attention. I shall say more about this presently.

Fifteen years ago the Government announced the scientific policy resolution. In an oftquoted statement. Jawaharlalji said in Parliament:

> "Science has developed at an ever-increasing pace since the beginning of the century, so that the gap between the advanced and backward countries has widened more and more It is only by adopting the most vigorous measures and by putting forward our utmost effort into the development of science that we can bridge the gap. It is an inherent obligation of a great country like India, with its traditions of scholarship and original thinking and its great cultural heritage, to participate fully in the march of science which is probablv mankind's greatest enterprise today."

And the statement continues:

The Government of India have accordingly decided that the aims of their scientific policy will be:

(*i*) to foster, promote, and sustain, by all appropriate means, the cultivation of science and scientific research in all its aspects-pure, applied and educational;

(*ii*) to ensure an adequate supply. within the country, of research scientists of the highest quality, and to recognise their work as an important component of the strength of the nation,

(*iii*) to encourage, and initiate with all possible speed, programmes for the training of scientific and technical personnel, on a scale adequate to fulfil the country's needs in science and education, agriculture and industry, and defence;

(*iv*) to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity,

(*v*) to encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom, and

(*vi*) in general to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge.

The Government of India have decided to pursue and accomplish these aims by offering good conditions of service to scientists and according them an honoured position, by associating scientists with the formulation of policies, and by taking such other measures as may be deemed necessary from time to time."

This is a historic statement, and is as relevant today, pertinent, as when it was first made. To implement the comprehensive policy enunciated in it is no easy thing, as is increasingly apparent. It requires energetic, sustained and coordinated action on many fronts; educational, scientific and political. And it also needs activisation and recognisation of the academies and scientific societies in the country.

Role of INSA

The Academy has been considering for some time, as Fellows are aware, the question of bringing about certain important changes in structure and functioning of the Academy so that it can promote more effectively scientific research in the country and the role of science in national life and affairs. As I said at the October 1973 meeting of the Academy—and it is a reiteration of what my distinguished predecessors have often emphasized—the role and work of the National Academy is very important for national development: for the growth of scientific research, and a 'climate' favourable to research and innovation, and welfare of the scientific community An important role of INSA is promotion of international scientific contacts. There is no substitute for an active well-organized National Academy enjoying the confidence and support of the scientific community, the Government, and the public generally. There are certain basic functions which no other agency can discharge adequately. The development of the Academy demands a continuing effort and earnest co-operation of the Fellows. We need to enlarge the number of Fellows admitted every year to the Academy. In several disciplines it is becoming extremely difficult for a person to get elected while still in the prime of his scientific creativity. The increase in yearly admissions, if adopted by the Academy, should make it possible to give due emphasis, in Fellowship elections, to newly emerging frontiers, and to multi-disciplinary and ultra-disciplinary areas of research. An increase in the yearly intake of Fellows is only one aspect of several other changes which are called for. To some of these I referred to at the October 1973 meeting.

Academy Medals for Young Scientists

The Academy has instituted, beginning this year, fifteen Medals to be awarded annually to young scientists, below the age of 30 years, in recognition of scientific achievement. Nominations would be invited on a wide basis. The awards will be made by the Council on the recommendations of the Sectional Committees. "Award Lectures" by the Medalists on their work may be published in the Academy Proceedings or separately. The success of the scheme would depend on the interest taken by the Fellows, and on our ensuring the highest possible standards in selection of the awardees.

Incidentally, when selection criteria are very stringent, as these ought to be, the probability of an 'undeserving candidate' getting through is negligible, but correspondingly the chance of an equally deserving candidate being rejected is not so—it can be quite large. This applies to all competitive selections: also to our Fellowship elections. The number of awards should therefore be neither too few nor too many. Also, it is good for everyone, those selected and those not selected, to remember the role of 'luck'. (That helps to mitigate the evils of snobbery and arrogance.)

Need for Science and Technology Act

May I now refer to a matter of wide interest and national significance. It is about the need for a 'Science and Technology Act' for our country. A comprehensive Science and Technology Act enacted by Parliament would be a natural and much needed follow-up of the historic science policy resolution fifteen years ago. Apart from other things, it would be an expression of the nation's determination to harness science and technology for national development. The Act could provide certain directives, and specify broadly powers and responsibilities of the agencies concerned with scientific research. and provide for a machinery for co-ordination and review of the national research effort. It is most desirable, and would be of great value, if a Science Report were submitted to Parliament every year and discussed in the House. The Science and Technology Act should ensure support, I do not need to say, to scientific societies and academies, and the Indian Science Congress Association. The Act might deal with certain aspects of environment and technology assessment. The Science Research Council and the National Environment Research Council have been established in the UK in accordance with the provisions of the UK Science and Technology Act 1965

Strengthening of Scientific Societies

We have a large number of scientific societies in the country, a few active and others not quite in that category. Their perennial difficulty is lack of funds and facilities, even the very minimum that any scientific society should have for it to function. They find it extremely difficult to meet obligations for publication of journals, monographs, and technical literature, because of the rapidly rising publication costs and totally inadequate resources. The INSA is no exception This is a very disconcerting situation The activisation of scientific societies and academies, and their publications, is of the utmost importance for growth of research and improvement in its quality. This would also benefit greatly science teaching, particularly at the post-graduate level. The involvement and participation of young scientists, and students, in activities of scientific societies should receive special emphasis The strengthening and development of scientific societies is a major task and a challenge for the scientific community The INSA has a special obligation in this regard.

In the context of the fundamentally new and far-reaching challenges and problems, deeply disturbing in some ways, which face society and science today, a (radical) reform of scientific societies and organisations is essential. The need is urgent. The difficulties are immense and somewhat similar to those facing the Universities.

University Research

I mentioned the universities. And as we all know the prime need of our universities is support of research. This includes also the agricultural universities. Research in the universities has as yet not received the high national priority which it should for the country's advancement. The output of university research is two-fold. It is new knowledge and new persons trained in research. University research is far more economical than comparable research in institutions divorced from teaching. In the universities research is done by staff and students jointly and the latter cost much less than full-time researchers. University research provides the base, the foundation, for the research effort of a country. If research within universities is poor and neglected, research outside the universities cannot flourish for any length of time. It has been said that a research institution, no matter under what auspices, will seldom last a generation as a creative enterprise, if it has no continuing (effective) contacts with young research students This under-scores the central role of university research in national development, and the extreme importance of close links between universities and research institutions, including the national laboratories.

In this context the recent case of Japan is of outstanding interest During the past decade the Japanese government spent on the state universities half of its total budget for research and development (The total R & D budget for 1972 was 374 million yen) This greatly enlarged the capabilities of the universities for training of high quality scientists and engineers and to deal with new scientific developments relevant to the industrial growth of Japan As is well-known Japan's per capita GNP rose from US $300 in 1958 to more than 5 times by 1970, which shows a fantastic growth rate The GNP actually achieved in 1970 was three times the forecast made in 1960. The R and D policy of Japan is now undergoing a major shift in emphasis from economic growth to social welfare in the light (hindsight) of the adverse effects of unchecked industrial growth.

The Fifth Five-Year Plan

The Fifth Five-Year Plan (1974-79) document recognises that in the past research in the universities, though crucial for national development and self-reliance, received only a "meagre support". The Fifth Plan provides for an outlay (plan and non-plan) on Science and Technology of Rs 1,568 crores, as against Rs 376 crores in the Fourth Plan. The figures for the earlier plans are I=20; II=67; and III=131 crores.

The total outlay envisaged for the Fifth Plan is Rs 53,411 crores. The GNP figures given in the document are: 1973-74=Rs 50,495 crores, 1978-79=Rs 68,130 crores. The population estimates are: 1971=547 million; 1974=581 million (41·4 per cent in 0-14 age group); 1979=637 million; 1984=686 million

The S and T outlay is nearly 3 per cent of the total Fifth Plan. The distribution of Rs 1,568 crores among different sectors is shown in the following Table reproduced from the Plan document (Part II, p. 231).

It is apparent that the universities do not at all receive the emphasis that they ought to. This is indeed unfortunate. It may be noted that of the total of Rs 54 crores for R and D work in the universities and IIT's (about Rs 9 crores for the IIT's) an amount of Rs 20 crores "would be earmarked for the projects identified by the NCST (The National Committee on Science and Technology)". It is not indicated how the NCST would discharge this responsibility. It is a matter which needs most careful deliberation if scarce resources are to be utilised to best advant-

Fifth Plan outlays on science and technology in different sectors

			(Rs in crores)
Name of department	Plan outlay	Non-plan estimated	Total
	(1)	(2)	(3)
Food & Agriculture	125 00	57 00	182 00
Irrigation	38·00	*	38 00
Power	15·00	*	15 00
Heavy Industries	70 00	—	70 00
Steel	20 00	—	20 00
Mines	69 00	—	69·00
Industrial Development	25 00	—	25·00
Petroleum	16·00	—	16 00
Chemicals	15 00	—	15·00
Electronics	20·00	—	20·00
Commerce	5 00	—	5·00
Shipping	10·00	—	10·00
Transport	9·00	–	9·00
Atomic Energy (R&D)	111·13	125·30	236·43
Science & Technology	109·98	75·00	184 98
Council of Scientific & Industrial Research	104·50	150·30	254·80
Space	90·00	82·50	172·50
Supply (National Test House)	2 50	2·50	5·00
Health	21·70	*	21 70
Family Planning	14·30	*	14·30
Works & Housing	23·75	—	23·75
Education & Social Welfare—UGC & IITs	54·00	—	54·00
Anthropological Survey of India	0·85	2·33	3 18
Communication	32·28	*	32·28
Railways	—	40·00	40·00
Meteorology (& Institutes)	30·00	*	30·00
Civil Aviation	0·80	—	0·80
Information & Broadcasting	0·50	—	0·50
Total	1033·29	534·93	1568·22

*Does not include non-plan outlay of R & D institutions in the Department.

age. It is proposed, according to plan document, to set up a Science and Engineering Research Council (SERC) "as an autonomous organisation sustained by the Department of Science and Technology where leading R and D organisations and UGC would be associated, the scheme would provide for multi-institutional and multi-disciplinary research in frontier areas of Science and Engineering". The Department of Science and Technology would support, it is heartening to note, "the plan programmes of the following institutions, viz , Indian National Science Academy, Bose Institute, Indian Association for Cultivation of Science, Raman Research Institute, Birbal Sahni Institute of Palaeobotany, Wadia Institute of Himalayan Geology, Indian Science Congress Association, Maharashtra Association for Cultivation of Science, Himalayan Zoological Park and Natural History Society."

I presume the list is not meant to be exhaustive, as several well-known professional societies are not mentioned

Human Implications of Science

In today's world almost every aspect of life is deeply influenced by—for good or bad—and dependent on science and technology. But not much is known and understood, and there is even less of public awareness, of the complex and dynamic interphase and interation between science, technology, and society. This is largely responsible for lack of a rational and coherent policy for technology development and its exploitation. It calls for research effort, on a massive scale, both nationally and internationally.

No longer can science and humanism survive in isolation. Ignorance and disregard of human implications of scientific and technological innovation is not only a grave environmental hazard but it puts man's very survival in jeopardy. As a classic case we may recall the interview between Niels Bohr and Churchill a few fateful months preceding the use of atomic bomb on Japan. As recorded in '*Britain and Atomic Energy*' 1939-45 (an official history, HMSO, London): "practically the whole of the time (of the interview) was consumed in argument on irrelevant points. Bohr was unable to bring the Prime Minister's mind to bear on the implications of the bomb....When he asked as he left if he might address a memorandum on the subject to Mr Churchill, the Prime Minister replied that he would always be honoured to receive a letter from Professor Bohr but hoped it would not be about politics. Bohr came away greatly disappointed at the way the world was apparently governed, with small points exercising a quite irrational influence "We did not speak the same language," said Bohr afterwards. Churchill retained a very disagreeable memory of the interview".

Science is universal, ecumenical. All barriers are alien to science. But the world is tormented with divisions of all kinds Greed, fear, violence, poverty, pestilence and pollution are rampant everywhere In a world in which stockpiles of thermonuclear weapons, as also the number of nations holding them, is continuously on the increase, where Hydrogen-bomb laden planes patrol the skies, and where inter-continental missiles are kept zeroed and ready to take off to pulverize skulls by the millions, it is no wonder that people feel frustrated. And the youth see no future before them. The world may not blow up in the near future, but who can tell? Who can assure hundreds of millions of men, women and children who want to lead peaceful, honest lives that they will not be reduced instantaneously to ashes, at some unpredictable moment.

The yawning economic gap between the rich and the poor countries is rapidly increasing—it is all the more oppressive as there is generally little "cultural gap" between the rich and the poor nations. There is a desperate need to check the present uncontrolled and callous exploitation of technology and natural resources. If this continues unabated, with attendant gross disparities within and between nations, it can lead only to unmitigated disaster. On the other hand the future holds great promise if science is pursued with zest and dedication and technology is wisely used in the true interests of the community, and not for narrow sectional ends dedicated by selfishness and mistrust. The human use of Science and Technology is no easy goal. It demands vision, courage, and above all faith. The scientific community has a major and primary role. A first imperative is to promote its varied aspects, at national and international levels, of the human implications of science and technology.

Crisis of Spirit and Youth

It cannot be denied that there is a deep anguish, an agony of the soul which afflicts thinking men today, particularly the youth. In a fundamental sense this crisis is inherent in the nature of science itself Science has eroded, largely destroyed, the meaning and purpose which our ancestors assigned to the Universe. But it has provided no substitutes, nor promises any. In fact the strength and power of science lie in its total denial, inability to answer the question: What is the purpose of the Universe? Why the Universe? Why men?

Let me take an example. There is a severe drought, a famine in some area, or a manned spacecraft is in some mortal danger. Will prayers, earnest and heartfelt, be of any avail?

The 'official' scientific answer would obviously be—I believe—'No' and rightly so. But what about the 'personal' views of scientists? Do none believe in the value or efficacy of prayer? Would no 'expert' think of God when in serious trouble, illness or danger.

Modern science makes the conclusion inevitable that in the operations of nature there is no place, no role whatsoever, for the supernatural. The reign of reason and logic is supreme. This is no simple, no obvious conclusion. It was not as all apparent in the days of Newton, and Akbar, not to think of earlier times.

No considerations of purpose, divine or human, can enter the domain of objective science The exclusion is complete. Science is objective, not subjective. If we ask, what purpose do the stars in the sky serve; the answer of astronomy is: "The stars serve no purpose whatever" In the realm of science any other answer is inadmissible: it would be absurd. To think of any purpose or goal—for the universe (or for an parts of it) it alien to science. It is incompatible with it.

But, for the "I", purpose (teleonomy) is everything, without it there is nothing. What is the bridge, the connecting link, if any, between the objective science and the subjective "I"? How to resolve the flagrant contradiction between the "determinism" that science predicates and the "freedom of the will" which the "I" experiences In truth, we are no nearer to an understanding of the "mystery" than the insight and wisdom provided by the Upanishads. In this context, Erwin Schroedinger's remarkable book 'My View of the World' (1961), is of deep interest. The recent development in quantum physics, cybernetics, and molecular biology emphasize that—if anything—the mystery is far deeper than ever thought before. It is one thing to recognize that we have no "solution", but altogether another thing to assert, as some people do, that there is no "real problem", no "mystery" about the mind-brain relationship. The distinction is important. Otherwise there is a danger that science is which today mankind's greatest intellectual and fruitful enterprise may, in the end, smother man's spirit instead of enlarging and enriching it.

There is a real need for a philosophy of human implications of science. To this India, in the years to come, could and we hope would make distinct and enduring contributions. To understand the human implications of scientific advance, and to reflect that understanding in policies and programmes, it is to bring about a transition from science and technology at the expense of man to science and technology for man· From non-humanistic to humanistic technology. This may perhaps appear a dream today, but then today's dream is often the reality of tomorrow. That is the most inspiring, unforgettable lesson of science.

And in thinking of human implications of science, let us remember, in the light of modern knowledge, that a new-born child of any people is capable of imbibing any culture, if exposed to it early enough. Man is one "family". Divisions are man-made and their overcoming is in man's own hands

SOME THOUGHTS ON TRUTH

D S KOTHARI

(delivered at New Delhi, 1975)

It has been a great honour and privilege for me to serve the Academy as its president for two years. I am thankful to the Fellows of the Academy for their kindness and co-operation

I apologise at the outset for my temerity and naivete in the choice of the subject: *Some Thoughts on Truth.*

Recent developments in physics — I have particularly in mind the complementarity principle, and epistemological basis of quantum mechanics — throw a new light on the notion of *truth* and *reality*, and of scientific explanation. It has an important bearing on the cultural and spiritual crisis man faces today. The new trends have a highly suggestive resemblance to certain aspects of Indian philosophic thought. Erwin Schroedinger's *My View of the World* (Cambridge University Press, 1964) and the introduction by von Weizascker to Gopi Krishna's *The Biological Basis of Religion and Genius* (1973) immediately come to mind. All these are no sufficient grounds to entitle me to speak on this subject. What I may plead in my favour is that if only truly knowledgeable people spoke and wrote—and none others—it would make communication dull and spell ruin for the publication industry. And more than that, I believe, it would adversely affect advancement of knowledge itself, especially scientific knowledge. We all know that experts by their training and inclination feel uneasy and fearful to ask questions which clash with prevailing fashion and style of their disciplines (Most people over thirty are experts of one sort or another). Many problems despite their extreme significance and relevance tend to be ignored because these do not neatly fall into well established disciplines. Sometimes their very existence is doubted and denied by the "established" experts. A novice also has a role.

Science is the search for truth. The practical value of science has been astonishingly great, beyond all expectations. A selfless. unfaltering devotion to truth and the use of knowledge for man's upliftment are the ideals of a scientist. Truth is what all earnest scientists seek. But what is *truth*? What is true knowledge? Is there an objective criterion of truth? Are there no real truths except mathematical, and possibly scientific? What about ethical truths? Is not pursuit of science itself a moral commitment, an ethical truth, not derivable from science? Are not scientific truths and ethical truths complementary? We cannot derive from science why some people love science, or why there should be science at all. *Are there any absolute truths or are all truths relative*? Are these meaningful questions or otherwise? Is it possible to define truth precisely, at least in the domain of mathematics? An elucidation of some of these questions, especially the last one, is a major achievement of our century and one of the greatest in the entire history of man.

What is Truth?

What is truth? I take a dictionary, say, *The Little Oxford Dictionary*, and look up the word 'truth'. I find that: "truth= being true; loyalty, accuracy, integrity, etc; that which is true, true statement, 'account', belief, etc; reality fact". I now look up the words 'loyalty', 'accuracy', and all the rest that are supposed to give the meaning of the word truth— (For example: reality=real existence; and existence=fact and fact=what is true). A dictionary can only tell me what "truth" is, if I know what "reality" is; and I know what "reality" is, if I know what "existence" is; and I know what is ' existence" if I know what is "fact"; and I know what fact is, if I know what "truth" is. We are back at the starting point A dictionary is of no avail for definition of truth, or as a matter of that of anything.

There are many things which most people know nothing about, but there can be no person, never was, or ever will be, who has no notion of truth. We know *intuitively* the distinction between truth and untruth, at any rate in most cases. But intuitive concepts can lead to logical contradictions The atomic concept provides an example of profound historial significance So long as it is an intuitive concept—that is, an atom is pictured as an extremely small ball—the atom can be imagined to be divisible into parts, and those into still smaller parts, and so on till its elements vanish into "nothingness". There is no escape from this logical contradiction The atomic concept was rejected by the Vedantic and Buddhist thinkers (notably Nagarjuna) The way out of the difficulty has proved to be totally unexpected. It has taken more than two thousand years The discovery of the quantum of action has shown that the atomic concept is *not intuitive—an atom is not a "small ball"* An atom is both *indivisible* and *divisible*, and it involves no contradiction because of the *non-intuitive* nature of the concept The "antinomy of the liar" is another well-known example.

Suppose a person makes a statement: "I do not have courage to speak truth". This is an innocent way of saying "I am a liar". You may be inclined (I do not know) to accept this statement as true (call it S). If you do, then you are admitting that the person has courage to speak truth. This means that S is false. So if you assume that S is *true* the conclusion is that S is *false*. And if you assume that S is false, then you are admitting that the person has courage to speak truth; and hence S, the statement made by him is true. The same statement S cannot be *both true and false*.

Take another example. Suppose a person says, "X exists". Its negative is "X does not exist". The two statements are contradictory. Suppose he says "I do not exist". If I accept this to be true, I must conclude that the person exists, otherwise how could he make the statement? To say "I do not exist" is to assert "I exist". To deny one's own existence is only to affirm it A person cannot experience his *own* mortality. *Consciousness cannot experience its own coming into being (birth) nor its own extinction* That is totally impossible

The origin of the logical contradiction in these examples is *self-reference*. If we say that a sentence "S" is true, and if "S" itself contains the word "truth", we are obviously in for a vicious circle, an antinomy In the second example the paradox arises because the notion of "I" includes necessarily the notion of existence.

Suppose I say "I do not have courage to put my hands into hot water". No contradiction arises if you assume this to be true This is unlike the case when I say "I do not have courage to speak truth". On the other hand there is an inherent contradiction, because of self-reference, in the following two statements:

The sentence below is true
The sentence above is not true.

Call the first sentence S_1 and the second S_2. If I assume S_1 *to be true*, I must accept S_2 to be true, which says that S_1 *is false*. If I assume S_1 is false, then S_2 is false; therefore S_1 is true. We cannot get out of the contradiction. S_1 *is both true and false.*

[A well-known example is Richard's antinomy, formulated by J. Richard in 1905. Consider the sequence of expressions W_1, W_2,.... which define all possible properties of integers. Then for a given integer n, either n has the property represented by W_p, or it does not have the property. We write symbolically $W_p\ (n) =$

$+1$ for the first case and $W_p(n) = -1$ in the second case. Now the expression $[W_n(n) = -1]$ defines property of integer n, and so it must be represented by some W in the sequence $(W_1, W_2 \ldots .)$ Suppose it is W_q. Then for every n for which $W_n(n) = -1$, we have by definition of W_q, $W_q(n) = +1$. Put $n = q$ and there arises the contradiction $W_q(q) = -1$ and $W_q(q) = +1$.]

A logical definition of truth is confronted by the antinomy of the liar A way out of this fundamental difficulty we owe mainly to Tarski [A. Tarski: *Logic, Semantics, Metamathematics*, Oxford (1956); *Scient. Am.*, June (1969)]. The starting point is an analysis of the basic features of *Common or natural* languages The characteristic of common language is its universality—its *unlimited* competence in giving expression to our ideas. Basic to definition of truth is the concept of a "formalized language", that is, language restricted to a precise specified vacabulary and rules of syntax. We can regard the language of a standard text book of science as an example of "formalized language". The notion of truth can be precisely defined for "formalized languages", but only by explicitly recognizing that no such definition can be constructed for common languages. A consequence of this is that there must exist meaningful statements which though *unprovable* are nevertheless true. *Truth* and *proof* are not equivalent *(even in mathematics)*. That is an amazing development, not at all easy to comprehend.

Mathematical Truths

How do we know that the three angles of a triangle add up to *exactly* two right angles! Physical measurements on actual triangles can only tell us that the statement is true approximately—within the limits of observational errors. We cannot eliminate observational errors altogether. *That is impossible.* If we use a straight ruler to draw a straight line, how do we know that the straight ruler is straight. Compare it with another. But is the comparison ruler straight? Why not use rays of light to form a triangle, its three sides made of three intersecting light rays? But the question still remains. How do we know that light travels in straight lines? If the space itself is "curved", as it probably is on a cosmological scale, then for a triangle on the cosmological scale the sum of its observed angles will not be two right angles. [It appears that the observed angle subtended by a "rigid rod" instead of decreasing linearly with distance, tends to increase for distances exceeding red shifts larger than $\lambda/\lambda_0 \sim 2$]

The simple fact is that no measurement, no experiment or observation what soever, is possible without a relevant theoretical framework.

No Theory, No Experiment

An experiment is a test of its underlying theory An experiment is designed to text some specific theoretical result or prediction, and if the experimental result disagrees with the theory, it is a call to improve the theory. Improvement of theory is a continuing process resulting from a systematic continuing confrontation with experiment A radical improvement often comes from incorporating new mathematical ideas—the new mathematical ideas may themselves have been encouraged by experimental developments. But often there is a big time lag between discovery of new mathematical ideas and their meaningful incorporation in scientific theories Mathematical truths as regards their validity or "reality" are completely independent of *experience.*

A mathematical theory or discipline, say Euclid's geometry or analytical dynamics, starts with a small number of *axioms* and *undefined terms* The truth of the axioms and the meaning of undefined terms is *assumed* to be known intuitively. It is not open to question or investigation within the framework of that theory. The development of the theory consists in proving new theorems on the basis of the axioms, and theorems already proved. There are no prescribed methods of proof nor precisely defined criteria. Proofs are acceptable so long as the arguments used are self-evident, that is, intuitively convincing. The new theorems, unless trivial, are of course first "discovered" and then proved. Discovery is an inspired guess, a flash of insight. It is not a step by step process, but a sort of quantum jump of a well-prepared imagination. A rational account of a discovery, the proof, follows and not precedes the discovery (as every research worker knows).

Godel and Tarski: Proof and Truth not Equivalent

The notion of proof is as old as mathematics but, what is called *formal proof* is a comparatively recent development. A *formal proof* makes no use of intuitive arguments howsoever convincing these may appear to be It uses only a small fixed number of "rules of proof" (rules of inference), so simple in content as to be self-evident. A *formalized theory* depends only on its prescribed set of undefined terms, axioms, and rules of proof. It is a remarkable achievement of modern mathematics that intuitive arguments which over the last 2500 years have led to great discoveries can be replaced in most cases by *formal proofs* It is not always necessary to do so It can be left to a small band of mathematically gifted logicians; the rest can carry on effectively, as they do, making new discoveries, with intuitive arguments.

The development of the new notion of *formal proof* has led to a totally unexpected discovery. It is so profound and novel that its significance, mathematical and philosophical, would take a long time to be generally appreciated. K Godel (1931) demonstrated, as is well-known, that any non-trivial formalized mathematical system, e.g., Theory of Numbers, must necessarily be *incomplete*. In other words within the system there must exist mathematical statements which can neither be proved nor disproved. The system must contain *undecidable* statements We cannot get over this situation by including the undecidable statements in the set of axioms of the system The modified system will still contain new undecidable statements, different from those of the original system. Undecidable statement, is an inevitable accompaniment, ingredient, of every non-trivial mathematical scheme.

Take the celebrated Fermat's statement. For integers x, y, z, and n, the equation $x^n+y^n=z^n$ has no solution, for n greater than 2. No one yet knows whether this is provable or undecidable What Godel's theorem asserts is that the Number Theory necessarily contains *undecidable* propositions. But it is most unlikely that a specific meaningful example could be identified.

We have considered the notion of *formal proof* and the profound consequences following from it. What about the notion of *logical truth*, that is, what is the definition of "true sentences"? This is a very abstract and intricate subject We have to distinguish, as mentioned earlier, between formalized language (or object-language) and the richer (meta-language) which contains the formalized language The conclusion reached by Tarski is (*Logic, Semantics, Metamathematics* p 273).

"*For every formalized language a formally correct and materially adequate definition of true sentence can be constructed in the metalanguage with the help only of general logical expressions, of expression of the language itself, and of terms from the morphology of language—but under the condition that the metalanguage possesses a higher order than the language which is the object of investigation*

If the order of the metalanguage is at most equal to that of the language itself, such a definition cannot be constructed".

The notion of proof can be translated into formalized or object-language. On the other hand, the notion of truth cannot be so reduced. It lies outside the "object-language". It belongs to the "meta-language" (or common language). All provable statements are true statements. But the converse is not true. Every formalized system worth its name must contain statements which are true but not provable within the framework of the system.

The *a priori* notion of truth helps us to make fruitful choice of axioms and rules of proof for a formalized system. It serves as a valuable and inspiring (but not unfailing) guide for development of mathematics As Tarski observes: "There is no conflict between the notions of truth and proof in the development of mathematics, the two notions are not at war but live in peaceful coexistence" [*Scient. Am*, June 1969].

It is apparent from the foregoing discussion that a formal, analytical treatment of intuitive concepts can lead to unexpected results. The distinction between *proof* and *truth* is probably the most significant achievement. To mention another striking example, the concept of *area* (on curved surface) and of *volume* comes to mind About forty years ago, A Tarski and S Banach showed that if we discard intuitive (geometrical) ideas of volume, and seek to define the concept in terms of the abstract *measure theory*, the result is unbelievably strange, through mathematically indisputable.

To quote from E Kasner and J Newman, *Mathematics and the Imagination*, G Bell and Sons, London, 1961, p 207: "There is a way of *dividing a sphere as large as the sun into separate parts so that no two parts will have any point in common, and yet without compressing or distorting any part, the whole sum may at one time fitted snugly into one's vest pocket.* Furthermore the pea may have its component parts so rearranged that without expansion or distortion, no two parts having any points in common *they will fill the entire universe solidly, no vacant space remaining either in the interior of the pea, or in the "universe"*. And they continue: "Surely no fairy tale....can match this theorem of hard, mathematical logic. Although the theorems of Hausdorff, Banach, and Tarski cannot, at the present time, be put of any practical use....they stand as a magnificent challenge to imagination and as tribute to mathematical conception "

To ask the question whether the theorems of Hausdorff, Banach, and Tarski are true, is no different from asking the question whether it is true that the sum of the three angles of a plane triangle equals two right angles? The answer is identical in the two cases. *The theorems are true.* And this irrespective of the fact that the one appears so obvious and the other so incomprehensible. The highly abstract HBT theorems express mathematical truths, which, how so counter to common sense these may seem, are nonetheless incontrovertible in the "world of thought". But this is not to imply that there corresponds to these theorems a physical reality, that is, these have a physical application But if past experience is a guide, deep mathematical ideas sooner or later turn out to be relevant to our understanding of the natural world (May be, the elucidation of the singularities attending gravitational collapse call for the HBT concepts· We do not know). The question whether a mathematical truth has a physical or scientific relevance is a question not in mathematics but *outside* it. It is a question that belongs ultimately to experience—to *experimental science.* It cannot be decided by intuition and reason only It requires an appeal to experience, to sensory knowledge. The distinction between mathematical truths and scientific truths is crucial The basis of one is *reason*, of the other *experience* The two, of course do not function in isolation from one another. But the two are different reminding us of, and related to, the difference between *mind* and *matter.* Mind can conceive spaces of any number of dimensions (and with different types of matrices), but it is experience of the exterior world which leads us to conceive physical space as three dimensional.

The roots of primitive experience—

concepts such as proximity, identity, truth—are possibly embedded in the genes. A new born child has from the very moment of birth considerable, surprising competence to deal with the world around him, as shown by some recent studies in child development. A child is born as an extremely competent individual The competency has been acquired through the biological evolutionary process of our species extending over millions of years. We may say in a manner of speaking that every child is born with certain *truths*, the basis of its competencies, engraved within it. These truths are as much an expression of the genes as is the body

As atoms are prior to genes so also we should regard mathematical truths as prior to evolution. James Jeans in a famous lecture many years ago declared God to be a pure mathematician. Of great interest are the observations of M Delbruck on the *a priori* aspect of the concept of truth in mathematics with its far-reaching consequences. To quote Delbruck [Nobel Prize Address (1969): *A Physicist's Renewed Look at Biology, 20 years later*].

> "Thus even if we learn to speak about consciousness as an emergent property of nerve nets, even if we learn to understand the processes that lead to abstraction, reasoning, and language, still any such development presupposes a notion of truth that is prior to all these efforts and that cannot be conceived as an emergent property of it, an emergent property of a biological evolution Our conviction of the truth of the sentence, "The number of prime numbers is infinite", must be independent of nerve nets and of evolution, if truth is to be a meaningful world at all".

A machine like a computer "knows" *proof* but not *truth* (as distinct from proof). Its "language" is "object language" and not natural language It is possible that *the mystery of truth is embedded in the mystery of time itself.*

Theories in Science

We spoke about truth in logic and mathematics. In natural science, as described earlier, a theory or explanation is always tentative, waiting to be replaced by an improved, more comprehensive theory. The only way a successful theory can contribute to further advancement of knowledge is to suggest new problems and experiments which provide new tests for the theory. Failure of a theory is frustrating and painful for its authors; but it is failure, and not success, which leads to improvement of existing theories All this is now common scientific philosophy, thanks to the epochal contribution of Karl Popper. His famous formula ($P_1 \rightarrow TT \rightarrow EE \rightarrow P_2$) expresses the quintessence of the method of science. Here P_1 stands for problems which serve to test the theory; the testing of the theory is symbolized by TT. The testing leads to elimination of errors (EE) in the theory. The improved theory suggests new problems P_2; and the process repeats itself. *A Scientific theory is always provisional.* It is guide to further development, to its own replacement.

It is apparent that there is, nothing like a "true theory" That represents an *ideal* a limit that can never be attained. The road to a "true theory" is an unending one It is an endless quest The notion of "true theory" serves as a motivation for continuing improvement It functions as a true ideal, inspiring but unattainable.

Syadvada Logic

At this point I should like to say a few words about the logic of *Syadvada*, also called *anekantavada* or *astinasti* vada (*Syad* means "may be"). This was formulated by Jain thinkers more than two thousand years ago. It is the logic of complementarity per excellence. It should be of great interest, both scientific and ethical, in the modern context Its relevance to statistical concepts has been discussed by P C Mahalanobis and J B S Haldane (*Sankhya*, May 1957).

According to the *Syadvada* scheme every fact of reality must be described in *seven* ways. These are combinations of affirmation and negation:

(1) Existence, (2) Non-existence, (3) Occurrence (successive) of Existence and Non-existence, (4) Inexpressibility or Indeterminateness, (5) Inexpressibility as qualified by Existence, (6) Inexpressibility as qualified by Non-existence, and (7) Inexpressibility as qualified by both Existence and Non-existence.

Syadvada asserts that knowledge of reality is possible only by denying the *absolutistic attitude.*

We may notice that the superposition principle of quantum mechanics provides an illuminating example of the *Syadvada* mode of description Let Kets $/\alpha'>$ and $/\alpha''>$ be the different eigenstates of an observable α for a quantum mechanical system. Let $P>=/\alpha'>+/\alpha$, we have the *Syadvada* mode of description:

(1) System is in state $/\alpha'>$
(2) System is not in state $/\alpha'>$, but in $/\alpha''>$
(3) System is both in state $/\alpha'>$ and $/\alpha''>$ represented by the mixture $/\alpha'><\alpha'/+/\alpha''><\alpha''/$
(4) System is in an inexpressible state represented by $/P>=/\alpha'>+/\alpha''>$
(5) System is in an inexpressible state and in state (1), represented by $/\alpha'><\alpha'/+/P><P/$
(6) System is in an inexpressible state and in state (2), represented by $/\alpha'><\alpha''/+/P><P/$
(7) System is in an inexpressible state and in (3), represented by $/\alpha'><\alpha'/+/\alpha''><\alpha''/P><P$

Syadvada asserts that a thing is "A", and it is also "not A" and both "A and not A", and so on. *It is an exhortation to investigate reality from all different possible viewpoints.* It is not a doctrine of indifference or passive acceptance of statements and also their negative. It is just the contrary. It demands our ascertaining the conditions, the coordinate frames as it were, under which a thing is "A", the (different) conditions under which it is "not A", conditions under which it can be both "A" and "non-A" and so on.

An oft-quoted illustration of *Syadvada* is the dialogue between Mahavira and his favourite disciple Gautama [Nathumal Tatia, *Studies in Jaina Philosophy* (1951), 22-23]

'Are the souls, O Lord! eternal or non-eternal?

The souls, O Gautama! are eternal in some respect and non-eternal in some respect

With what end in view, O Lord! is it said that the souls are eternal in some respect and non-eternal in some respect?

They are eternal! O Gautama, from the view-point of substance, and non-eternal from the view-point of modes And with this in view it is said, O Gautama! that the souls are eternal in some respect and non-eternal in some respect

Is the body, O Lord! (identical with) the soul or is the body different from it?

The body, O Gautama! is (identical with) the soul as well as it is different from it.'

Unlike *Syadvada*, in Aristotelean logic a thing is either "A" or it is "not A". It cannot be both "A" and "not A" at the same time. Here the main concern is an examination of a thing from one particular standpoint, and not from all different standpoints A Jain logician may contend that this is a meaningless effort Any meaningful examination involves more than one standpoint A thing can never be examined twice from an *identical* standpoint, for, if nothing else, at least the two instants of observation are different. Nothing is exactly repeatable But in asserting this, we ignore the fact that differences between *relevant aspects* of the two (different) situations may be so small as to be negligible in practice. *Repeatability is the essence of scientific observation* It is possible to think, but I am not competent to judge, that the *Syadvada* logic did not particularly encourage quantitative observation Its emphasis was on philosophic enquiry.

[Reference to Aristotle's logic brings to mind the 4×4×4=64 moods of syllogisms (Every syllogism consists of three propositions). Of these 64 moods only 24 represent true syllogisms. [e g., Jan Lukasiewicz, *Elements of Mathematical Logic* (1963)]. There is here a curious coincidence (numerological) with the genetic code The code has three "letters", each letter representing one of four nucleotides. The 4×4×4=64 possible combinations generate 20 amino acids. Adding the three 'nonsense' triplets the number is 23]

Ethical Truths: Gandhi's "Experiments"

I said earlier that scientific truths and ethical truths are not contradictory but complementary There can be no science without ethics and an ethical society Equally, in the modern world there can be no ethics without science It seems that the most significant ethical lesson of science is that "experimentation" in ethics is as necessary for its development, its practice and philosophy, as it is for progress of natural science. And the method of ethical "experimentation" is *Ahimsa*

Mahatma Gandhi gave to his autobiography the title. *The Story of My Experiments with Truth* He wrote (in 1926) "What I want to achieve--what I have been striving and pining to achieve these thirty years—is self-realisation, to see God face to face, to attain *Moksha* (salvation). I live and move and have my being in pursuit of this goal". The experiments which he narrates "are spiritual, or rather moral; for the essence of religion is morality". And he says: "I claim for them nothing more than does a scientist...I have gone through deep self-introspection, searched myself through and through, and examined and analyzed every psychological situation. Yet I am far from claiming any finality or infallibility about my conclusions. One claim I do indeed make and it is this. For me they appear to be absolutely correct, and seem for the time being to be final.. And so long as my acts satisfy my reason and my heart, I must firmly adhere to my original conclusions".

In the concluding chapter of the autobiography Gandhiji says· "My uniform experience has convinced me that there is no other God than Truth...and. the only means for the realisation of Truth is Ahimsa... After all, however sincere my strivings after Ahimsa may have been they have still been imperfect and inadequate . But this much I can say with assurance, as a result of all my experience, that a perfect vision of truth can only follow a complete realisation of Ahimsa". And he continues "I must reduce myself to zero. So long as a man does not of his own free will put himself last among his fellow creatures, there is no salvation for him. Ahimsa is the farthest limit of humility"

There is a chapter with the title, *Face to Face with Ahimsa* This refers to the first *Satyagraha* in India initiated by Gandhiji after twenty one years of "preparation" in South Africa Writes Gandhiji about his meeting, early in 1917, with the indigo cultivators at Champaran (Bihar) "It is no exaggeration, but the literal truth, to say that in this meeting with the peasants I was face to face with God, Ahimsa and Truth".

Ahimsa is pure selfless love for every human being, and indeed for every living creature It is non-injury in *mind, word and deed.* Action which does violence to one's conscience, to the little voice within the inner voice, is a departure from Ahimsa. [To kill an animal for sport is a greater fall from Ahimsa than to kill for food]. *Ahimsa is a moral concept essentially.*

In the pursuit of Ahimsa the importance of *Syadvada* has been emphasised by Gandhiji. He says: "[But] all my life through, the very insistence on truth taught me to appreciate the beauty of compromise I saw in later life that this spirit was an essential part of Satyagraha". "...Without Ahimsa it is not possible to seek and find truth ..As a coward, which I was for years, I harboured violence I began to prize non-violence only when I began to shed cowardice. The path of true non-violence requires much more courage than violence", says Gandhiji.

Gandhiji's experiments are spiritual, ethical experiments. The underlying basis of morality is self-control or self-conquest through self-suffering "Liberation from the bondage of the self constituted the only way towards a more satisfactory society", observed Einstein It is generally recognised that ethical truths have little meaning if there be no *self* (mind or soul) as distinct from the physical body To say this is not to imply that the individual self physically survives dissolution of the body (...it is morally necessary to assume the existence of God", observed Kant.)

The feeling or *demand* within every individual to discover one's *Swadharma* or duty, one's purpose in life—how so much this demand may wane temporarily—must be recognised as a fact of experience, a truth The discovery of *Swadharma* is greatly helped by knowledge and reasoning but ultimately, it transcends reason Reason and therefore science, cannot provide answer to the questions To what end? To what purpose? It can only lead to an infinite regress.

Science is Objective: Science is not Enough

The attitude towards science of the great pioneers of the scientific revolution—Galileo, Kepler, Newton—was that to do science was akin to rendering divine service. The Holy Bible was the First Book of God. The Second Book of God was Nature. This Book was written in the language of mathematics. To decipher this Book was to worship God. Newton says in the *Principia* (Book III) that the "beautiful system of the sun, planets and comets could not be born from mere mechanical causes" It could only proceed from "the counsel and dominion of an intelligent and powerful Being". Newton believed that God would have to intervene from time to time to maintain stability of the solar system [It was Laplace, who a hundred years later demonstrated, availing of developments of mathematical ideas and techniques, that such divine intervention was unnecessary]. But despite all this, it was Newton's *Principia* which laid the foundation for the autonomy of science He says "He (God) is omnipresent not *virtually* only, but also *substantively;* for virtue cannot subsist without substance. In him are all things contained and moved, yet neither affects the other: God suffers nothing from the motion of bodies, bodies find no resistance from the omnipresence of God It is allowed by all that the Supreme God exists necessarily; and by the same necessity he exists *always and everywhere*" The crucial assumption that "God suffers nothing from the motion of bodies; bodies find no resistance from the omnipresence of God", was a declaration of *objectivisation* of natural science.

The gradual elimination of the supernatural and occult from explanations of natural phenomena was greatly encouraged, in the early stages, by the striking success of mechanical laws to account accurately for the motions of the planets, moon, and comets.

Today we take objectivity of science as synonymous with science itself The reign of reason is supreme in science. [We are, of course, thinking of science as such, and not its applications which often time are totally devoid of reason.] Whenever there is a discrepancy between theory and experiment, we seek to modify the theory, and not attribute the discrepancy to any supernatural cause or agency. And the domain of science is continually expanding, extremely rapidly, as we all know. Yesterday it took the atom within its folds. Today it is the gene, the sub-atomic particles, and galaxies situated at the very limits of the Universe. Tomorrow it may be the brain; and what not! It seems as if autonomous science will soon—some day—encompass, and engulf, *everything* But what about the *psyche*, the "I"?

In a scientific description of nature (including man) there is no place for: "To what purpose"? To what end or goals? Astronomy tells us much about the stars, but to the question "What purpose do the stars serve?" Its only answer can be "No purpose whatever". Any other answer *within* astronomy, within natural science, would be absurd.

The exclusion from natural science of subjectivity, that is "I", is total Within the strict confines of natural science there is no place for *self*, *moral truths*, *love*, *beauty* and *God*.

The basis and strength of science is its objectivity Science is alien to purposes and goals It admits no arguments which smack of any teleonomy Yet the very pursuit of science—choice to devote one's life to science and not to something else—is a moral decision Science is objective, but love (or hate) of science is subjective Science is *causal* It is deterministic But to the individual freedom of choice is a fundamental fact of direct personal experience. As H Poincare' said· "It is just as impossible not to act as a free man when we act than it is not to reason as a determinist when doing scientific work... We can hope that...to infinite intelligence the two attitudes...would seem equally legitimate..."

The objective world of science and the subjective world of personal experience appear as two entirely different worlds.

The world of science has "room for everything, but none for man" (A Koyre). This is deeply frustrating. It is agonizing. People carried away by the overwhelming success of science, or rather technology, tend to believe that *what is not in science is not there at all: it does not exist.*

And yet the crisis is of our own making. It is a result of our own "forgetfulness". The objectivity of science is secured by excluding from its domain all subjectivity. That is the definition of the methodology of science. The exclusion of the "I" from science is the convenant between science and "I". The roots of the present crisis of (Western) man lie in wrongly conceiving that what cannot be described by science—what is not within the perimeters of science—is necessarily contradictory to science (and therefore non-existent). It is a misplaced case of the domination of Western mind by Aristotlean logic

What we need to recognize is that *reality* has not one facet but many. Science is one facet The different aspects of reality are complementary to one another, and not contradictory. This approach is characteristic of the *Vedantic* thought. Let me quote Erwin Schroedinger from his great little book. *What is life?* (1944)

> "So let us see whether we cannot draw the correct. non-contradictory conclusion from the following two premises:
> (*i*) My body functions as a pure mechanism according to the Laws of Nature
> (*ii*) Yet I know, by incontrovertible direct experience, that I am directing its motions, of which I foresee the effects, that may be fateful and all-important, in which case I feel and take full responsibility for them.
>
> The only possible inference from these two facts is, I think, that I—I in the widest meaning of the word, that is to say, every conscious mind that has ever said or felt 'I' —am the person, if any, who controls the 'motion of the atoms' according to the "Laws of Nature".
>
> "In itself, the insight is not new The earliest records to my knowledge date back some 2,500 years or more. From the early great Upanishads the recognition *Athman=Brahman* (the personal self equals the omnipresent, all-comprehending eternal self) was in Indian thought considered, far from being blasphemous, to represent the quintessense of the deepest insight into the happenings of the world. The striving of all the scholars of Vedanta was, after having learnt to pronounce with their lips, really to assimilate in their minds this grandest of all thoughts."

To disregard the complementarity of scientific and ethical truths—the complementarity of matter and mind, of body and soul—can lead only to de-personalization and de-humanization of life. The highest type of scientific activity is not possible without a supreme faith in science and in man. This is a moral quality. There is no inherent contradiction in the same person being an intellectual giant and a spiritual pigmy, but in real life it is most unlikely. When asked (during a serious illness) whether he was at all afraid of death, Einstein said: "I feel such a sense of solidarity with all living things that it does not matter to me where the individual begins and ends". And he said, "There is nothing in the world which I could not dispense with at a moment's notice". How close to Gandhi are the ethical convictions of Einstein! He regarded Gandhi as "the greatest man of the age".

The most significant lesson we can learn from the marvellous developments in atomic physics in our century is not to be misled by apparent contradictions, but try to understand the complementarities underlying them. The great lesson we owe primarily to Niels Bohr is that we must learn to take the complementarity approach seriously not only in science but in life. And the philosophy of complementarity is essentially the philosophy of *Syadvada* and of the *Upanishads*.

It is time I said something about complementarity itself. I have used the word frequently. I must admit I have not used it consistently It is because the concept is not an easy one; it is entirely novel at any rate in the modern context; and my thoughts are not clear. That makes the subject interesting, but also irritating (not only to others but to me equally).

In speaking of the complementarity of two aspects or viewpoints, an important element is that the situations under which the two aspects occur are *different* in some essential respects. Complementarity of the two aspects implies some irreducible element of incompatibility between them. This is necessary.

The complementarity principle has emerged, in the modern context, from the study of atomic phenomena. The complementarity of the wave and particle aspects of matter is well-known. The two aspects are incompatible. An experiment which demonstrates the wave aspect would automatically exclude demonstration of the particle aspect; and vice-versa. Why so? It arises from an interaction, inherent in the nature of thing between a system and the measuring instrument The interaction cannot be eliminated even under ideal conditions. It cannot be reduced below a certain minimum limit, defined by the Plancks's constant, for any conceivable experiment—or "thought experiment". The interaction disturbs the state of the system under observation. An experiment which provides some information about an atomic system, inevitably destroys (in general) some other information which we had about the system from an earlier experiment on the system. We cannot accumulate information indefinitely, because of an unavoidable interaction between the system and the measuring device, and the accompanying disturbance of the state of the system. This is totally different from the situation in classical physics. If interaction between a system and the measuring device could be *completely ignored*, made zero—as was the assumption in classical physics—then, in principle, the measuring instrument becomes redundant. Not so in quantum mechanics! The complementarity principle is forced upon us because there can be no measurement without a certain minimum interaction; and the experimental arrangements for determining different properties of an atomic system are, in general, *incompatible* with one another.

In fact, if we could think of an experiment which is *inherently* incapable of giving us information about some obvious, characteristic property of the system, then such an experiment is likely to reveal unexpected features of the system. This in a sense is the essence of complementarity mode of thinking in physics. As is well-known, according to von Neumann and E P Wigner, the conceptual problem of *measurement* in quantum mechanics brings to the fore a role of human consciousness which has no analogue is *classical physics*. But I shall not pursue this here.

There are levels of Complementarity—a hierarchy To take a rather trivial example the particle and wave aspects of an electron in an atom are complementary; and there is also the complementarity of the particle and wave aspects of the atom which contains the electron. *Physics* (objectivity) and *psyche* (subjectivity) are (perhaps) complementary. I may in this context refer to the monograph by C G Jung and W Pauli: *The Interpretation of Nature and the Psyche* (1955).

To sum up: our conclusions are simple·

Firstly, there should be effective and deliberate opportunities for interaction between science and philosophy (understood in its widest sense) This is likely to be of immense mutual benefit Science is not enough. In promoting interaction between science and philosophy the Universities and the Academies have a special obligation. A chair in philosophy of science is an obvious suggestion.

Secondly, the complementary mode of thinking should have a much wider scope, than at present It holds great potentialities not only within science, but for everyday life, and in human affairs generally Indian philosophic thought (particularly *Syadvada*) is of great relevance to understanding and future development of the complementarity paradigm.

Thirdly, the notion of truth—in mathematics, science, or ethics—is *regulatory*. *There are no absolute truths Truth is a guide to action to ceaseless striving*

To pursue truth in all its varied aspects of which the ethical is doubtlessly the most important—with zest, courage and dedication to the best of one's ability and strength, is man's highest duty and obligation That is the greatest lesson science holds for us. That is also the greatest need of the world today

Dr Benjamin Peary Pal, FNA*

(Elected to the Fellowship, 1946; President, 1975-76)

Dr B P Pal was born on 26 May 1906 at Mukandpur, Panjab. He was awarded the Ph.D. degree of the Cambridge University in 1932 and D Sc (*h c.*) by the Universities of Punjab, UP & Orissa, Haryana Agricultural University, Banaras Hindu University and Sardar Patel University He is a Fellow, Royal Society, London; Honorary Fellow, Linnean Society London; Foreign Member, Lenin All Union Academy of Agricultural Sciences; Honorary Member, Japan Academy & Genetics Society of Japan and Foreign Member, French Academy of Agriculture. He was General President, Indian Science Congress Association, President, Indian Society of Genetics and Plant Breeding, Indian Botanical Society, Horticultural Society of India, and Society for the Advancement of Breeding Researches in Asia and Oceania. He is the recipient of Padma Shri (1959), Padma Bhushan (1968), Rafi Ahmed Kidwai Memorial Prize of the Indian Council of Agricultural Research (ICAR) (1957), Birbal Sahni Medal of the Indian Botanical Society (1962), Srinivasa Ramanujan Medal of the INSA (1970), Barclay Medal of the Asiatic Society (1971), Aryabhata Medal of the INSA (1980), G.P. Chatterjee Memorial Award of the Indian Science Congress Association (1982), Sir William Jones Medal of the Asiatic Society (1982) and Sanjay Gandhi Memorial Award in Environment and Ecology (1983)

Dr Pal is known for his contribution to crop improvement, particularly the breeding of superior disease-resistant wheat and of roses His 15 years term as Director saw further enhancement of the role and status of the Indian Agricultural Research Institute As the first Director-General of the reorganised ICAR, he was significantly associated with the first phase of the Green Revolution Later, as Chairman of National Commission for Environmental Planning and Co-ordination he has contributed to a great extent to planning for environmental conservation.

**Address:* P-11 Haus Khas Enclave, New Delhi 110 016.

WHEAT AND ROSES

B P Pal

(delivered at Waltair, 1976)

I consider it a high privilege to have this opportunity of addressing the Fellows of the Academy and other scientists today. Some previous Presidential Addresses have been concerned with a presentation of the author's own research work while others, specially of those who were no longer actively engaged in research, have dealt with aspects of science policy or other matters of general interest to scientists In my case, I have decided to give an Address which does make some reference on my own work but also deals with some issues which are vital to agricultural productivity in the country The combination of wheat and roses is perhaps a little unusual but what I had in mind when I chose the title, was the thought so beautifully expressed by Muslih-uddin Sādi in his '*Gulistan*' where he has said:

> "*If of thy mortal goods*
> *thou art bereft,*
> *And from thy slender store two*
> *loaves alone to thee are left,*
> *Sell one, and with the dole*
> *Buy hyacinths to feed thy soul*"

Sādi has referred to hyacinths which were well known to him, but, if we take the whole world, it is the rose which symbolises for man— beauty, love and the finer things of life. Although rice feeds a larger number of people in the world, wheat is usually referred to as the "staff of life", and its importance is well brought out in the following extract from the preface of a book on wheat by K S Quisenberry and L P Reitz:

"Wheat is many things. To a botanist, wheat is grass. To a chemist it is organic compounds, and to a geneticist, a challenging organism. To a farmer, it means a cash crop, and to a hauler, freight To a labourer it means employment; to a merchant it is produce To a miller, it is grist, and to a baker, flour The banker sees it as chattel and the politician as a problem Animals browse and feed on it and it sustains parasites The conservationist uses it as ground cover In religion, it is used as a symbol The artist and photographer see it as a model To millions it provides a livelihood, and to millions more a life-giving food

Wheat has been all of these things and many more for a very long time Man has used wheat as a food since prehistoric times There is some evidence that it was first used in a parched form Wheat was apparently grown in the Middle East as early as 10,000 to 15,000 BC, and it appears in writings from as early as 550 BC Many of the plant's characteristics were probably well-known to man 2,000 years ago, when it evidently was grown for food . The important fact is that man has depended upon the wheat plant for himself and his beasts for thousands of years and hundreds of generations

The experience of history and the weight of modern knowledge of nutrition, however, indicate that mankind will not, should not, and, indeed, dare not abandon wheat A global wheat failure would be catastrophic, a disaster few nations could survive even one year."

It is because of these considerations that I decided to give an address about wheat and roses. Let us take wheat first!

We know from the well known researches of Vavilov that the bread wheats i.e., the wheats which are most predominantly used for providing bread, originated in the northwestern corner of the Indian subcontinent including also the area of

Afghanistan. Wheat has therefore been associated with the ancient civilization of India from times immemorial. There is reason to believe that the great civilizations of Babylonia, Crete, Egypt, Greece and Rome were also based on wheat as one of the principal food crops, and it is reported that the Chinese grew this cereal as far back as 2,700 BC Men of ancient times attributed the origin of wheat to supernatural agencies. Thus the Chinese regarded wheat as a direct gift from heaven, while the Egyptians believed that it was introduced to the earth by the Goddess Demeter and Tryptolemus. Samples of wheat have been found in pre-historic human habitats, for instance, in the rubbish heaps of lake dwellings in both Italy and Switzerland.

In more recent times the wheats of the world have been studied quite thoroughly. More than 15 species are recognised, some of them growing wild, while the others are cultivated The wheats fall into three natural groups based on their chromosome number and some other attributes The wheats belonging to the first group i.e , the diploid group with 14 chromosomes, are unimportant but in the tetraploid group *Triticum durum*, the macaroni wheat, is still important in some areas, particularly for the preparation of certain types of wheat products. It is the hexaploid group of wheats, however, which is most important, and in this group, the species *T. aestivum* is the bread wheat *par excellence*. Wheat is usually made into flour, though from the flour it may be consumed in many forms such as loaves, chapattis, etc Wheat is considered to be one of the best of the cereals, and in addition to starch it supplies proteins, minerals and important vitamins.

Let us now consider briefly the position of wheat in India. India was a great producer of wheat long before the famous wheat-growing areas of the United States, Canada and Australia were developed or even discovered. Investigations by Marshall and others have provided evidence that wheat of a cultivated species was being grown about 5,000 years ago in the Mohenjodaro region. Although the area under wheat in India is less than that under rice or sorghum, it is the staple food of a large section of the population of the Indian Subcontinent. It was natural therefore that when scientific research on modern lines began in India in the early years of the current century that wheat should be one of the crops which received maximum attention.

In this early period, A Howard and G L C Howard, assisted by A R Khan, conducted work on the improvement of wheat. From the wide range of wheat varieties existing in the country they were able by simple selection to identify the variety '*Pusa 4*' which became world famous for its grain quality. A number of other wheats followed all of which were of reasonable, high-yielding capacity, considering the level of farming which was then practised, and most of them had good grain quality. The phase of simple selection was followed by that of simple hybridization between varieties, to provide new combinations of characters. One of the important varieties thus produced was '*Pusa 52*' which achieved a wide distribution in the country. Wheat breeding work was done not only by the Imperial (now Indian) Agricultural Research Institute but also by the research centres in some of the States in India.

I was associated with another phase of wheat improvement which immediately followed the first phase. Although, as already mentioned, wheat varieties were now available which combined fairly good yielding capacity with good grain qualities, the problem of diseases had not received adequate attention. Fortunately the wheat crop in India is not attacked severely by any insect pests, but the rust diseases caused by the different species of a fungus, loose smut and some other diseases exacted considerable toll of the produce. The rust diseases have been particularly difficult to deal with since in the case of the black and the brown rust, hybridisation can take place on their respective alternate hosts, while in the case of all three of them, frequent mutations take place resulting in new races, some of which may be more virulent than the existing ones. Races of the rust fungus may also be carried from one country to another by wind currents. The number of such races (which are morphologically indistinguishable but differ in their power to infect different varieties of wheat) is very large, and constitute a most difficult problem for the plant breeder, especially as new races keep coming up and attacking wheat varieties which previously were considered to be resistant

A programme of breeding was accordingly initiated by me with the cooperation of Prof K C Mehta of Agra. In the beginning, this consisted in first making crosses between Indian varieties with good agronomic characters and exotic varieties which had the desired rust resistance, though in other respect they were not suitable for Indian conditions, and testing the resultant progenies. Three sets of crosses were made, and, in due course, varieties resistant separately to the black rust, the brown rust and the yellow rust, were obtained Multiple crosses were then made on a large scale to bring together resistance to all the three rusts, combining it with suitable agronomic attributes and adaptability to conditions in India As a result of 18 years work, the variety '*NP-809*' was evolved, this being the first wheat to be obtained as a result of a planned plant breeding programme, which was resistant in a large measure to all the races of the rusts then reported in India. It had another very useful asset in that it was also immune to the widespread loose smut disease. Besides '*NP*-809', a large number of other varieties were produced both at the IARI and by the State Departments of Agriculture, which were substantial improvements on the older varieties.

Yet another phase of wheat improvement began when in 1963 a large variety of wheat material containing the dwarfing genes from Mexico (these genes were originally identified in the Japanese variety '*Norin-10*' which was subsequently brought to the United States, in 1948, and from there introduced into new varieties in Mexico by Dr N E Borlaug, the famous wheat breeder) was introduced through the courtesy of the Rockefeller Foundation and the Mexican Ministry of Agriculture. Out of this material, two varieties, namely, '*Sonora-34*' and '*Lerma-Rojo*' proved to be successful when tested under a wide range of conditions, under the All-India Wheat Improvement Project. These short-strawed wheats responded well to high fertility conditions and were readily accepted by the farmers in spite of their relatively poor grain quality compared to that of the best Indian varieties The wheat material from Mexico was soon crossed by the Indian wheat breeders with Indian varieties to produce new types some of which are proving very useful. It was the new varieties of wheat plus the appropriate agronomic technology which were responsible for the breakthrough in wheat production in India, and which more than doubled the output of wheat, in a short period of only five years. This breakthrough in wheat production has been the backbone of what has been called the *Green Revolution*

In the case of the Punjab, one of the important wheat-growing States, the yield per hectare increased from 901 kgs in 1950-51 to 2243 in 1969-70 (M S Randhawa, 1974). Individual farmers competing for the Krishi Pandit awards have reported very high yields indeed; for instance a farmer from the Khandwa block in Madhya Pradesh reported a yield of 55·16 quintals per acre. But while there has been a substantial overall increase in wheat productivity especially in the northwestern States, and while individual farmers in certain areas have also set up records of high wheat production, the level of wheat production in the country is nowhere near the maximum which could theoretically be achieved.

In the Table below which I have taken from S H Wittwer (1974), the average, the top, and the record crop yields in the USA which is one of the most agriculturally advanced countries of the world, in 1973 are given The figures are in bushels per acre

Table: *Average, top, and record crop yields in the USA (bushels per acre)*

Crop	1973 Average	Top	Record
Corn .	94	230	306
Wheat .	*32*	*135*	*216*
Soyabeans .	28	30	110
Sorghum	63	200	320
Rice	28	130	350*
Potatoes	385	1000	1400
Sweet Potatoes	130	600	900
Barley	41	150	212
Oats	49	150	296
Sugar Beets .	20**	40**	54**

*Obtained at the International Rice Research Institute, Los Banos, Philippines, in 1970 from a total of crops grown in one year.
**Tons per acre.

It will be seen that even in that country there is a big gap between the record yields and those obtained by the generality of the farmers In view of the great need for maximizing crop production, and particularly food production, from the available land on this earth, to feed the huge population which is increasing at an alarming rate in many parts of the world, what is it that scientists can do? Before we try to attempt to answer this, let us now turn for a moment to the world of roses.

India is one of the ancestral homes of the modern garden roses and *Rosa moschata* has been growing wild in the Himalayas from ancient times But there has been no clear evidence of the growing of roses in gardens in India until we come to the Mughal times. After that, roses have been popular in India and there has also been an industry producing roses for rose oil and water. After Independence, there has been a tremendous increase in interest in the garden roses. There appear to be good potentialities for the export of cut roses to Europe in the winter months when because of climatic conditions, the industrialised countries of Western Europe cannot have fresh roses, whereas the cool weather period is the best for this purpose in India and roses can be grown out of doors all the year round An attempt which was made just three or four years back to export roses to some Western European countries had only partial success but there were several reasons for that and the conclusion, in my opinion, should not be drawn that there is no scope for capturing a part of the European market. Israel, for instance, has a flourishing export trade of cut flowers to Western Europe. There appears to be no good reason why India which is only three hours by jet plane should not also be able to participate in this trade if appropriate steps are taken after a careful study of the market requirements.

Some of the countries in South and South-Eastern Asia like Indonesia, Thailand, Malaysia, Singapore and Sri Lanka have a valuable export trade to Europe of flowers such as orchids It is a great pity that India, with its wide range of climatic conditions and a large number of technically trained people is not able to do what these countries have done Perhaps one reason is that floriculture has not received the recognition which it deserves in this country Flowers tend to be regarded as a luxury for the well-to-do classes That is not correct The culture and trade in flowers can provide employment to many persons, besides the aesthetic pleasure which flowers afford to people in all walks of life, especially the children. After man has been able to obtain the material wants of food and other vital necessities, he surely needs the finer things which inspire him to live a better life So while we must concentrate primarily on producing food and economic materials, we can surely by proper planning afford to allocate the relatively small areas required for beautifying our country and our homes with ornamental plants.

Let us now go back to the problem of making a spectacular breakthrough in wheat and other essential food plants.

At a recent Symposium on *'Basic Sciences and Agriculture'*, organised by the Indian National Science Academy, attention was drawn to the fact that a great deal of basic research is necessary if the agriculture of the future is to safeguarded The possibilities, for example, of producing entirely new economic plants; of increasing the photosynthetic efficiency of plants; of test-tube pollination and fertilisation as a new method for raising inter-specific and intergeneric hybrids, of new methods of rodent and pest control, and of new techniques of using biological nitrogen, and many other problems and possibilities were highlighted.

I do not propose to discuss here the details of the many problems which will require the attention of scientists, nor go into the question of how and where the researches should be undertaken My main purpose today is to draw pointed attention to the fact that the recent advances in agriculture have given us a little breathing space in which to plan and implement really far-reaching endeavours in the fields of science and technology, to meet the future requirements of the human race. It is absolutely necessary that the agriculture of tomorrow should be very highly productive, and characterised by stability of production and qualitative adequacy. It should provide productive employment and lead to agrarian prosperity but in such a way that it ensures "*harmonious co-existence of plants, animals and man in a mutually symbiotic and prominently productive bio-system*". This is a great challenge and demands a great response.

If we are to rise to the occasion and achieve the desired objectives, we will have to act very quickly and in a different way from what we have been doing so far.

In war time, as every one knows, if something is required very urgently, say, a new war machine, be it a new type of aircraft or submarine or tank, the Government assembles immediately the persons with the required scientific and technical expertise, and gives them a direction to produce a blueprint of the required machine in the shortest possible time This is followed up by appropriate executive action so that all the materials and components required are made available without hitch or delay and work proceeds apace. Under the stress of war a great deal of work is done, involving high level team work, which does not usually happen during normal times. When the problem of maximising food production is so overwhelming and so urgent, when we know that millions of people are hungry and under-nourished, should not something like what is achieved in war time be organised, to ensure that this gravest of problems facing the human race is properly solved? Should not the authorities bring together the appropriate persons in the fields of agriculture and related sciences and charge them with the duty of planning and initiating a research programme which will within a period of, say, 10 years, give us wheat varieties and also rice varieties (these two being the major food crops) which can give yields of 20 tonnes of grain per hectare year after year, under an agronomic technology which is feasible and economic? From the possibilities which have been enumerated by plant physiologists and others such a target does not seem to be impossible but the will to do it must be there and the resources required must be forthcoming

Besides the cereals, we must also similarly plan for huge increases in the productivity of the root crops which have, according to experts, a far higher potential than grain crops. When we succeed in evolving these super types of high yielding crops with good nutritive quality, then the agronomists will have to devise new multiple and intensive relay cropping systems. But while planning for all this let us make a start on breeding the 20-tonnes-per hectare wheat varieties.

In my opinion the Indian National Science Academy should take the lead, with the co-operation of the Indian Council or Agricultural Research and other scientific organisations, in organising a symposium in the near future at which this problem will really be thoroughly discussed and illuminated.

Such a conference obviously will not be in a position to draw up a blue print but it could furnish an expert description of the food problem in its totality and provide the necessary guidelines so that, if those in authority decide that *Project Wheat* (this is the tentative title I am giving to it) must be taken up on the equivalent of a warfooting, the next steps will become clearer.

I thank you.

RANDHAWA, M S (1974) *Green Revolution.* Vikas Publications, New Delhi,

ADDRESS BY THE PRESIDENT

B P Pal

(delivered at Bhubaneswar, 1977)

For two years I have enjoyed the high honour of being President of the Indian National Science Academy. I wish to again express to the Council and the Fellows of the Academy my deep debt of gratitude for this distinction which they bestowed upon me.

As I remarked when I addressed the General Body Meeting last year, Presidential Addresses have varied a great deal in their subject—some Presidents have delivered strictly scientific addresses while others have discussed either the progress of the Academy or other matters of importance to scientists. When one attempts to do any kind of stock-taking on the termination of a tenure of office, one is reminded of the saying, "*Everybody sets out to do something, and everybody does something, but no one does what he sets out to do*" Put in other words, this statement implies that it is never possible for one to completely achieve the target which was set for accomplishment. There is perhaps much truth in this but at the same time this cannot mean that sometimes quite a lot cannot be successfully accomplished and some of my distinguished predecessors have certainly left a record of work for the Academy for which this learned body should be grateful.

The work of the Academy has been expanding and becoming diversified. For sometime, in its earlier history, the Academy, in the words of Dr Atma Ram, "*was perhaps more concerned with preserving the scientific chastity, than getting involved in functions which would bring the Academy face to face with various social problems and governmental responsibilities in the field of science*". However, to be fair it must be pointed out that at that time not only were the financial resources more limited but the Academy had not been given a charter to take up wider responsibilities. In due course the position of the Academy improved and the landmarks in its history have included the recognition by the Government of India that this was the premier Science Academy of the country, the decision of the Government to transfer the adhering function with International Scientific Unions under the aegis of ICSU from the Government departments to the Academy, the naming of the Academy as the body responsible for implementing the Indo-Soviet Joint Programme for Research in selected areas of Basic Sciences, and the introduction of the exchange programme with the Royal Society of London. The Academy also developed a relationship with the National Academy of Sciences of the USA, and an important Symposium on "*Water in Man's Life*" was organised a few years back.

Other important new activities were the financing of a number of projects in the Basic Sciences, and an attempt of popularising science by arranging a series of lectures including some especially for school children During the term of office of my distinguished predecessor, Dr D S Kothari, a significant scheme of identifying and giving recognition to young scientists was initiated and has been widely welcomed.

During the two-year period during which I have been President, the strengthening of activities of the Academy has continued but I do not propose to go into details as these are contained in the reports which are submitted by the Secretaries to the Council at each meeting. I will only mention in passing that, first of all, steps were taken to improve the condition of the building and gardens of the Academy Headquarters so that they may be worthy of the Academy. Then action has been taken to prepare a proper scheme for the strengthening of the Office of the Academy as an adequate infrastructure is essential to support the rapidly increasing activities of the Academy Plans have also been discussed for a new building which has become necessary in the context of the greatly increased responsibilities of the Academy, and taking advantage of its very central location, to develop it as a major centre for the holding of scientific meetings, conferences, and generally speaking, of scientific activities. I must admit that at the moment these plans are castles in the air, but we have had a sympathetic response from the Department of Science & Technology through which we receive our grants-in-aid from the Government.

The Basic Sciences Project is making progress and criteria have been established for selecting multi-disciplinary, multi-institutional schemes worthy of support by the Academy International activities have been intensified and during 1976, I had the privilege of leading the Academy's delegation to the USSR in response to the invitation of the Academy of Sciences there. The delegation was received with the utmost cordiality and friendliness and as a result of the contacts established there is reason to hope that the joint Indo-Soviet scientific programmes will be strenghtened still further. Again, during 1976, our Academy signed a protocol with the Japan Society for the Promotion of Science under which scientific collaboration between the two countries will take place Several scientific delegations from foreign countries have visited the Academy and some of them have expressed strong desire to establish relationships between their National Science Academy and our Academy. The Council of the Academy has welcomed such developments and has also expressed a hope that relationships with the Science Academies or equivalent bodies in the developing countries, and especially in our neighbouring countries, would be strengthened in the near future.

One matter in which I have been personally very much interested has been the co-operation with the other scientific bodies in the country. I am glad to say that we were able to organise, a few months ago, a Symposium on '*The Quality of Indian Scientific Publications*' under the joint sponsorship of this Academy, the Indian Academy of Sciences, Bangalore and the National Academy of Sciences, Allahabad Scientific Academies are developing in some of the States and I believe that the Indian National Science Academy should take the opportunity to build up fraternal relationships with them and assist them, if necessary. We should also similarly strengthen our links with the learned scientific societies.

One of the problem in holding International Conferences in India has been the difficulty experienced sometimes regarding free movement of scientists. I am glad to say that through the efforts of this Academy, the General Assembly Meeting of the International Union of Biological Sciences was successfully held at Bangalore this year This was possible because the Academy after consultation at a high level with the Government of India, was able to give an assurance to the IUBS that no *bonafide* scientist would have difficulty in entering the country to attend the Conference. This was highly appreciated by the IUBS which passed a resolution commending the facilities made available by the Academy and the Government of India

The publications of the Academy have received anxious attention and though we have not yet surmounted all the difficulties, one useful step recently taken has been the drawing up of a panel of presses to which the publications of the Academy can be sent, thereby avoiding the delay associated with searching for a new press every time. Library policy has also been given careful consideration. Here I must refer to the valuable contribution made in this respect by the late Professor P L Bhatnagar. It is hoped that by following the policy approved by the Council, the

Library of the Academy can be recognised as an unusually good reference library for particular groups or disciplines in the Basic Sciences.

I would like to make a special mention of the Seminar organised in 1975 by the Academy on "*Basic Sciences and Agriculture*" This brought together, for the first time, research workers from the Universities and from the Institutes of Agriculture and very useful discussions ensued. The value of the recommendations made at this meeting has been recognised by the Director-General, Indian Council of Agricultural Research, Dr M S Swaminathan, FNA, FRS In October 1976, as already mentioned, an important Symposium on '*The Quality of Indian Scientific Publications*' was held with the co-operation of the Indian Academy of Sciences and the National Academy of Sciences The reason for calling this Conference was to draw attention to the fact that though India has the third largest body of scientists and technologists in the world, and though there is a very large publication programme in the country, yet most scientists find it necessary to send their best papers for publication abroad There was thus need for giving thought to measures to rectify the situation One of the recommendations of the Symposium which needs to be followed up with full vigour is that in each major area of science, steps should be taken to have one outstanding Journal in India whose quality could attract the best papers of the country and also possibly some from abroad.

One other matter I must mention is the approval bestowed last year by the Fellowship on the proposal to increase the annual intake of Fellows from 15 to 30. This decision has been widely welcomed as a wise step in view of the large number of very able scientists in the country in the various disciplines of science

Having said something about the present work and position of the Academy, I would like to point to the future, and begin with a quotation from Mr R S McNamara who has said, "*The poorest quarter of the populations in developing lands risk being left almost entirely behind in the vast transformation of the modern technological society .. .. .. Can we imagine any human order surviving with so gross a misery piling up at its base*"? Referring to the position in India, Professor Meghnad Saha in the concluding portion of his Presidential Address in 1938 made the statement '*If we desire to fight successfully the scourge of poverty and want from which 90 per cent of our countrymen are suffering and lay the foundation of a strong and progressive national life we must make the fullest use of the power which a knowledge of Nature has given us We must rebuild our economic system by utilising the resources of our land, harnessing the energy of our rivers, prospecting for the riches hidden under the bowels of the earth, reclaiming deserts and swamps, conquering the barriers of distance and above all, we must mould anew the nature of man in both individual and social aspects so that a richer, more harmonious and happier race may live in this great and ancient land of ours*" In this context what is it that Science can do? Someone has remarked, "*In recent times, modern science has developed to give mankind, for the first time, in the history of the human race, a way of securing a more abundant life which does not consist in taking away from someone else*"

In an issue of *Nature and Resources* it is stated. "*It has become evident that while there are benefits to be realised from further research, the over-riding need is for refinement of integrated approaches to the planning and management of developmental programmes*" Again, referring to the food problem someone has said, "*Technically we know how to produce the food the world needs, but do not know how to put our knowledge into practice.*"

There is a very wide appreciation of the fact that science can transform our lives into something better but quite a few people have raised doubts as to whether the real good of humanity will be fostered by science because of its occasional misapplication or unbalanced application in relation to the most pressing problems of the human race. Here I would like to quote from that great thinker, Geothe, who stated, "*For what end is served by all the expenditure of suns and planets and moons, of stars and Milky Ways, of Comets and nebulae of worlds evolving and passing away, if at last a happy man does not involuntarily rejoice in his existence*"? Expressing almost a similar thought but in a different way, an American agronomist wrote in an article sometime ago: "*Unless mankind is wise enough and compassionate enough to devise a better food-security system, we may be seeing the beginning of the end of our civilisation.*"

I think the reference in this quotation to the quality of compassion is one of great significance for we must not confuse compassion with sentimentality. As someone has said, "*Sentimentality is no indication of a warm heart. Nothing weeps more copiously than a chunk of ice*". Can those of us who deal with science approach the overall problem of the use of science in a warm-hearted manner for the upliftment of our fellow-beings and also for the preservation of plants and animals in the world around us?

While there is a vast sea of misery and want in many areas of the world, in India also there is a very large section of our population which is denied at present even the basic food requirement recommended by nutrition experts. This legacy of poverty and want has come down to us for historical reasons which are known to everybody and a valiant effort is now being made in this country to try and wipe out this backlog, and to initiate and sustain a new era of contentment and prosperity Though the poverty of the Indian peasant has been heart-breaking, Kusum Nair in one of her books referred to "*the remarkable dignity and courage, despite the mud walls and the often empty cooking utensil*" of this large segment of our population. Though they have seen little of life's comforts, they have been sustained by their faith in religion and the rich legends from a past which is never very far behind them. Surely, they deserve all that modern science could do for them, if it is purposefully used. It was Pandit Nehru's firm belief and hope that science was the key which could open the door to a new and better life for our people.

I have referred to you these excerpts and quotations to provide the background against which the Academy has to function It is quite true that the Academy does not have the financial and staff resources to carry out large programmes of applied research and extension activity. These are being looked after by a number of our major scientific organisations like the CSIR, the ICAR, and the ICMR besides a great many voluntary agencies. But at the same time the Academy does have the most valuable resource of having within its fold, many of the most able scientists of the country, and it should be able to play a catalytic role in seeing that the fruits of research are channelled, without loss of time and in the most effective way, to the millions in our country who are in dire need of this. As our great philosopher and statesman, Dr S Radhakrishnan said, "*When the wick is ablaze at its tip the whole lamp is said to be burning*". So the Indian National Science Academy with the increased resources and support which it now has, should take up the challenge. There seems to be no reason why it cannot develop itself to perform the functions of a small but inspired brains trust in science.

One of the problems at present is how to obtain the increased participation of the Fellows of the Academy in such activities as organising discussions and lectures on matters of national importance, thereby bringing these to the notice of Government and the people, and for preparing authoritative status reports and special reports, especially on topics which have been relatively neglected because they fall between the boundaries of the major scientific organisations or for any other reason. The Academy will no doubt, as I have said earlier, build up closer relationships with the State Academies of Science and other learned bodies, so that there may be an integrated, overall endeavour to apply science for solving the many pressing problems of our country.

Dr Raja Ramanna, FNA*

(Elected to the Fellowship 1973; President 1977-78)

Dr R Ramanna, Director, Bhabha Atomic Research Centre, Secretary to the Govt of India, Department of Atomic Energy and Chairman, Atomic Energy Commission was born on 28 January 1925 at Tumkur, Mysore He was awarded the PhD degree of the London University in 1948. He was the Director General, Defence Research & Development Organisation and Secretary to the Govt of India for Defence Research. He is a Fellow, of the Indian Academy of Sciences and the Indian Society of Engineers He was awarded the Shanti Swarup Bhatnagar Award of the Council of Scientific and Industrial Research for Physical Sciences (1963), Padmashri (1968), Padma Bhushan (1973) and Padmavibhushan (1975)

Dr Ramanna's significant research achievements are in the field of design and commissioning of several research reactors, experimental and theoretical investigations of neutron thermalisation and neutron scattering, investigations in fission including a stochastic theory of the fission process, a geometric theory of atomic and nuclear structure, peaceful nuclear explosion and planning of accelerator programmes, fast reactor development and defence oriented research programmes He took active part in the design of the reactors in Trombay.

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*Address: Chairman, Atomic Energy Commission, and Secretary to the Govt of India, Department of Atomic Energy, 7th Floor, Central Complex, Trombay, Bombay 400 085.

FUNCTIONS AND ORGANIZATION OF SCIENCES IN INDIA

R RAMANNA

(delivered at Ahmedabad, 1978)

Nearly all my distinguished predecessors have used the occasion of the Anniversary General Meeting to express their views on the functions and organisation of Science in India. I feel that this year in particular, there is a special need for a close examination of these issues; for, while Indian science is on the threshold of great achievements, its organisation, as things stand to-day, may prove to be a source of hindrance to its early and effective application to the solution of national problems A delay in its application may lead to wrong conclusions as to the value of science to society itself and detract from the use of the methods of science to future developments, be it in the sphere of increasing the country's industrial potential or building a national personality reorientation of our philosophy to suit the 21st Century.

It will be recalled that in August 1977, the Council of INSA had issued a Press Release expressing concern over the inadequate realisation of the value of scientific methods, the limitations of such an approach and why the reorganisation of existing structures based on consultation was required in order to make it a more efficient tool for national development In the beginning, only some abstracted versions of the release appeared in a small number of dailies. However, its impact became more perceptible later.

I am glad to note that our two sister Academies, the Indian Academy of Sciences and the National Academy of Sciences, whose Presidents are both Fellows of this Academy, have also expressed views similar to ours, but perhaps in a more pointed manner as they were issued much later than the Press Release of the INSA Council and also after the decision of the Government to make major changes in the existing framework for scientific organisations. It is gratifying to note that a constructive view of these changes has emerged taking into account the importance of inter-disciplinary research activities It is a happy augury that the various Academies have independently come to almost identical conclusions As these conclusions taken in totality reflect the views of a large body of the science community, I take it to mean that Science Academies have an important role of an advisory nature to play in the formulation of science policy

Consultative processes are essential in a country like ours which has a large and diverse science structure and where the implementation of science policy is beset with enormous difficulties It is only a truly scientific society which can effectively examine the vast potential of present day science and suggest methods by which it can be kept in the forefront of development and not allowed to take on an imitative role, incapable of providing the required level of confidence needed to achieve national self-reliance. In a democracy, no set of scientists, however carefully they may be chosen, can replace the collective wisdom of a body like INSA, which has indeed been recognised by the Government, as early as in 1945, as the premier society representing all branches of science. I would, therefore, like to make a plea for the effective utilisation of the potential of the Academy for the benefit of the country much in the same way the USSR Academy of Sciences, the National Academy of Sciences, USA and the Royal Society of UK, are given pride of place in their respective countries. It is to be noted that the USSR Academy of Sciences even implements policy. We, as a body of scientists, should not appear to be bargaining for leverage. On the contrary, we are here only to give our considered advice. If confidence is reposed in us, we will naturally rise to the occasion in a manner that would enhance the prestige of Indian Science.

The reorganised National Committee on Science and Technology has as one of its members, the President of INSA and I believe that the views of the Council of INSA will be given due weight at the deliberations of the NCST. We take pride in the fact that the new Chairman of NCST is a distinguished past-President of INSA and he has already assured me that our views will be given special consideration.

Among those countries of the world which have a scientific base of some consequence, we are the one that spends the least on science In spite of this and in spite of the fact that our per capita GNP is amongst the lowest in the world, the quality of Indian science is greatly respected abroad and scientists and students from other countries come to us in fairly large numbers to share the knowledge developed in our laboratories. At various symposia organised by learned bodies, I am amazed to see the excellent quality of work in various disciplines contributed by research workers who are working under the most difficult conditions of financial, administrative and other forms of logistic support. By any norms of national planning, the allocations for science and technology should be increased if we are to survive as a modern nation and not become merely a geographical entity. The usual reason given against any increase of financial support is that we are a very poor country and that we cannot afford more. Some even say that we must cut on science to help one more villager to survive. If we have to make such cuts on science, it is not that one more villager will survive, but it is like cutting the very arm of the nation that can help uplift the villager. In our history, whenever we allowed ourselves to neglect science, we reached the lowest levels of degradation, especially during the 18th and 19th centuries, a stage from which we have not yet truly come out. We must never let this happen again. We must continue to support science as has been the policy since independence. This support should be enhanced, and widened in scope to cover the many developments that are taking place in the world.

Our country is a very large one and it should have every aspect of science operating at all levels, be it basic science (sometimes called ivory tower science) or the kind of "bare foot" technology intended to help in our rural programmes. There must be a continuous flow of knowledge from the high "ivory tower" to the down to earth level pervading through the entire scientific community. No branch of knowledge is unnecessary to a nation on the move. As an example of a discipline which does not give the impression of having any immediate value to the community, I may refer to abstract mathematics. This type of mathematics does not even have the possibility of being a source of entertainment like music or painting. It is there for its own sake, but is there anybody who would suggest that we should stop support to mathematics in this country? It is not that mathematics should be supported because it does not involve much financial investment (an incorrect statement in itself). It should be supported purely because such support would be in the spirit of involving ourselves in the very foundations of thought and structure of modern science. It is this very spirit that has allowed us to survive in the past as a nation with a remarkable continuity of culture. However, such an attitude requires our accepting the established laws of science as supreme. A very distinguished scientist abroad once said to me that it must be frightfully difficult to undertake scientific research in India because of the widespread atmosphere of non-science. There is no doubt that social conditions affect not only the growth of science, but even the use of scientific methods and, ultimately the absorption of science in the processes of change and development.

Over the centuries, the need for rule by law as a sign of civilised existence has come to be generally accepted Our lawyers clamour for this and swear by Manu, Mitakshara and Macaulay as though their pronouncements were the laws of God himself. But few have tried to critically examine their relevance to modern life. If you ask me why there is need for a large scale use of third degree methods in our police investigations, I would say that it is an outcome of the existing criminal procedure code itself There have been great advances in the forensic sciences, but how much of this has any value in our country? The greater use of science in detection of crime can result in lesser use of third degree methods and consequently lead to a lesser misuse of authority But this change requires an acceptance of the laws of science which have a better claim to being a creation of God In all material matters, the laws of science are supreme and such is the humility of science that when a more correct law is discovered, the older one is discarded if there is sufficient evidence to do so by a feedback process that is natural to it However, such ready acceptance of newer concepts requires our implicit faith in mathematics, statistics, the law of the exact science and their projection into Biology.

Sometimes people make a difference between scientific research and industrial research This is actually a very colonial view of industrial development. If the country really has to be industrialised in the fullest sense of the word, both must exist simultaneously. We can compare science and technology to a human body where the legs and hands represent industry, but the brain represents scientific research. If we do not have scientific research helping and controlling industry as a well assimilated part for our development, we will be merely importing not only equipment from outside, but even ideas This will completely place us in the hands of those who control industry elsewhere.

By its very nature, science requires nurturing of excellence which is wrongly levelled as "elitism". Good science can come only from those specially fostered in a special environment. While we can have mediocre music for use in restaurants and similar quality work of painters to be hung up on the walls of hotels, we cannot afford to have such a thing as a mediocre scientist. To keep a scientist working at his most effective and creative level, he has to be treated as something out of the ordinary His morale has to be kept at the highest level, otherwise, the investment made on him will all go waste. It is for this reason, advanced countries give a very special position to scientists and more so if their merit is indisputable. It is in the fitness of things that a scientist must be treated with solicitude which should be made a part of national concern rather than controversy. This acceptance of the scientist's position, however, requires a proper method of assessing him.

Research workers can be classified into three different groups· one just about to start his work, one at the peak of his activity and one who helps progress and promotion of science by his overall maturity and experience In the first category, the identification should normally be available through university gradings. Unfortunately, in India, this method of assessment is not satisfactory due to the large number of graduates being turned out in our universities In such an overcrowded situation, the identification of a single person who shows great promise becomes very difficult. Consequently, the training of a highly gifted person requires very special attention. It is for this reason that a secondary selection process from among those coming out of universities and their subsequent training is required for the proper development of a research worker in his earlier stages. At middle levels, when the research worker is at his peak of activity, the problem of identification is different as it requires great vision to recognise the merit of a man contributing at the frontiers of science.

The identification of good people at this level by means of newspaper advertisements is a futile exercise For one thing, a scientist in this group usually does not like to migrate from the place he is already in. He is suspicious of new environment and new colleagues. It requires tremendous persuasion to get a good scientist to work in another laboratory on a different set of problems which requires his expertise It is, therefore, hardly likely that he will respond to an advertisement. It is also difficult to believe that a UPSC type of interview is any better, specially when it takes the shape of a judicial operation. Unless the people who have to work with the scientist concerned are also emotionally involved in the selection process, a satisfactory identification will not result The so called objective method of selecting scientists by outside committees may satisfy norms, but fail to identify the best men. The problem is made worse when confidential reports are written on the candidate with a view to avoid any comments concerning his inadequacy with respect to the solutions of particular types of problems Whereas the objective identification of deficiencies is meant to help in locating a scientist in the environment most appropriate to his strength and weaknesses, it is often used in current selection processes as adverse remarks thus invalidating the use intended for such reports. Taking everything into account, a certain degree of rational bias in favour of excellence is an essential part of choosing the right man for scientific research. Unfortunately, it is true that there is a tendency to lay too much stress on the dangers of nepotism through relationship, caste, locality and other unpleasant factors While nobody can deny their existence, it is, I believe, a passing phase. Its incidence can be minimised by an appropriate choice of selection committees and by proper tradition and leadership In any case, there is always an element of risk involved in any attempt to recognise good people. Many of the difficulties one faces in selection operations are more due to shortage of posts and to the fact that salaries and posts are associated with one another. I have found from personal experience that if there is a delinking of salaries with designation, a younger man can take up more responsibilities because of inherent ability and not necessarily come in the way of the older scientist who may deserve a higher salary due to the passage of time In the choice of scientists at the very highest levels, other constraints of a non-scientific nature will naturally play a part and it is here that the Academies and learned bodies can play an important role in the assessment procedure

There has been considerable debate as to who is the user of any technical development that has come out of a laboratory I am afraid, it is certainly not the Ministry concerned To me the Ministry is a body which is meant to help the scientist to get on expeditiously with his work, to give all assistance to him in solving administrative problems and to act as a protective agency in legal and other matters that may arise in the coordination between a research laboratory and an industrial user. At least this is how, I recall, Dr Homi Bhabha defined the role of administration in scientific research. Unless administration has clearly understood its assistance role, there will be much cause for misgivings Due to historical reasons, many Government laboratories are classified as subordinate offices and are treated as such. This classification has come from British times and has remained unchanged if not in form, certainly in spirit The Ministry officials are only too conscious of the fact that all the statutory powers are with them and some of them even insist that they have the last word on the subject, purely for purposes of continuing the *status quo* It is possible that the Director of a laboratory can work smoothly with the Ministry, but keeping good relations becomes a major aspect of his activity involving severe compromise on several issues. Usually, the differences are not important when the concerned laboratory is involved only in routine operations. If, however, the Director wishes to make changes and do something out of the ordinary, which is the essence of scientific research and requires a constant process of delegation of powers, it is remarkable how departmental opposition comes to play, a fact noted by Lord Rutherford himself As I see it, by its very definition, a Ministry's approach is to routinise matters as much as possible and thus, if it is in direct control of a laboratory, only routine work will emerge On the contrary, all scientific work is based on continuous innovation, be it in scientific administration or in scientific research

It also does not follow that the user of any results of a laboratory is necessarily the industry concerned The main concern of the industry is to make profits and their approach to research is that it should lead to increased efficiency leading to increased production rates, but when new processes or new items of development which may have an overall national economic value are involved, the industry in general rarely shows much interest It is for this reason the autonomy of a laboratory has to be carefully preserved It is not for me to describe what autonomy immediately implies, and how it can be maintained, but I think the Academy should give serious thought to this and prepare a paper taking all aspects of the problem into account and make it available for public discussion.

I would now like to deal with an approach that has been considered as a solution to some of these problems and has been implemented as such. This is the process by which scientists are given secretarial power To me this seems to be an admission of defeat; for, it means that it is not possible to delegate powers to scientists to get on with their work and that unless a good scientist is sucked up into a secretarial structure, which is inevitable, he will not be able to survive or protect the interest of science I do feel that there must be a way out of this, whereby scientists holding high posts can be given appropriate powers, which would be commensurate with their stature and their level of functional responsibility. In some cases, where a scientist is of high calibre, it may be necessary to vest him with powers and a status that may be even more than that of a Secretary. The aim of the whole exercise should be to decentralise effectively decision making powers in order to truly promote as rapidly as possible the progress of science and technology

I have brought to your attention some of the difficulties concerning organisational matters of a laboratory But the purpose of a Presidential Address is not to merely categorise all these problems They are being brought to your attention more by way of examples so that a unified approach can be attempted and well before the end of the century we can say that India has a mature system for the organisation of science

If, in this context, INSA has to play an important role in the promotion of science, it has itself to undergo many changes It has a legacy of constraints by way of very inflexible statutory regulations copied from foreign institutions from the pre-independence era Since no changes to the statutes are possible without a three-fourth majority, it really means that no change is possible at all From previous experience it seems that out of a total of 387 Fellows, only about half of them take interest in the working of the Academy To improve participation, the Council has encouraged the functioning of Regional Chapters and I am glad to report that there is a continuous inflow of reports of activity from them, particularly those from Bombay, Calcutta, Hyderabad and Madras I would urge that if any changes are to be made to the Academy Statutes, the desire should come from the Fellows from the various regions. Any fundamental changes on important issues should be initiated only, with the full support of Regional Chapters. There is also the question of how much the Academy should recognise the excellent work being done in the country by Engineers and Medical men from the point of view of representation within the Academy. In order to get a proper assessment of the situation in these fields, I have suggested to the Council that other learned bodies should have an affiliation status to the Academy in some form, so that there is a continuing exchange of views on the problems of medical and engineering sciences and other fields of knowledge and between the learned bodies and the Academy. Close collaboration with State Academies would help in the collection of information concerning regional and rural problems

The Academy is here to help all the sciences in India and is committed to taking only a positive and helpful attitude Sometimes it is forced into rather unpleasant situations because among the body of scientists, a code of conduct and ethics has not yet come into organised existence We still have the old complaints of papers being published in a hurry with unverified results, insufficient credit being given to junior workers, plagiarism in some form or other, and above all, difference of opinion between scientists arising from sources of a non-scientific nature or personal prejudices. These, I presume, are essentially problems of a transitional nature which necessarily arise during the process of achieving maturity and growth. I would not give too much importance to these unless one can show that they are indeed causing definite damage to the image of Indian science At the same time, it should not be the intention of the Academy to shy away from problems and claim a state of *sanyasa* It should be amidst all scientific controversies bringing forth effective solutions without ever losing its commitment to basic principles.

INSA is essentially a scientific body and will recognise no other solutions on scientific matters except those under the principles defined by science. There is much controversy in the country about imponderables, such as the powers of miracle-men and the effectiveness of various indigenous cures and medicines. I know from my own experience that every other village in the South has its own methods of medication and that a large number of the Indian scientists retain their faith in miracle cures While I doubt the principles on which these cures and medicines are based, I must concede that several of them may indeed provide remedies, psychosomatic or otherwise. But, as far as we are concerned, we can recognise only one science and that is medical science Unless the claimed cures are understood with respect to biological processes based on principles of the basic sciences, they can continue only as unverified cures and that too only as long as they are not dangerous and do not lead to toxic side effects But they cannot be said to be part of medical science Objective statistical verification of all successes is an essential part of science

Another variation of the above syndrome which is very much in evidence in the international scene is the conclusion stemming from a non-scientific approach to current problems The International Atomic Energy Agency has, in recent reports, analysed the various application areas where the peaceful uses of atomic energy are bound to play an important and beneficial role in the future No less an authority than Academician Kapitza has recently expressed the view that for the effective exploitation of geothermal resources, peaceful nuclear explosions are necessary In spite of all this it is surprising that a large part of the world should stress on only the evil aspects of atomic energy. While the social obligations of a scientist, both in the national and international plane, cannot be lost sight of, it does not mean that they should succumb to new kinds of superstitions.

In conclusion, I would like to say that in the interests of science in India scientific bodies like INSA must strongly express their views in the formulation of Science Policy, and the organisation and administration of science, otherwise the very need for their existence will only be a very minor one

I would like to express my sincere thanks to the members of the Council who have been with me on all important issues

LIMITS AND LIMITATIONS

R Ramanna

(delivered at Hyderabad 1979)

The purpose of Defence Research is to keep the capability of the fighting forces at the highest level with the use of modern science and technology. This requires a cadre of well-informed and able scientists who are able to appreciate the value of the latest discoveries of science and new developments in technology to be of relevance to the defence effort and be in a position to translate these new developments to make it a viable tool for creating either new types of defence weapons or upgrade the existing ones to a higher quality In a way it is fortunate that the laws of physics, chemistry and science in general set a limit to what is possible in this regard and one can, therefore, in principle be guided by these laws as to the limits of such possible developments It is only after considering these limits, one can talk of the limitations of what is actually achievable as a result of financial, logistic and other constraints In this lecture, I propose to bring to your attention a few of the scientific constraints which will restrict development of weapon system from more basic considerations For this purpose, it is necessary to appreciate what a modern defence effort requires In spite of the risk of being very sketchy and naive, I shall state the following facts·

An army should have a tank having sufficient power to give it manoeuvaribility in the relevant fighting conditions. It should have a sufficient number of modern effective armaments of the desired power which is a common requirement for any other fighting system such as warships, submarines, aircraft and mobile vehicles. The type of armaments would consist of guns and mortars of various categories and fire, power, torpedoes, missiles, etc., and most of them will have to be controlled by electronic devices. Since tank manoeuvres are a nocturnal operation, modern night vision using infrared to visible light converters is essential

Our defence effort should include a strong navy especially because of the large coast line A strong navy implies effective working groups in naval design, design of submarines, study of the problems of corrosion in sea water, detection of other naval aircraft in the vicinity and communication between vessels. The growing application of electronics to warfare calls for a strong group in naval electronics which I shall call navionics

Modern warfare depends very much on the appropriate aircraft for specific combat operations; be it for an activity deep inside another country for supporting army manoeuvres or even for mere transport Aircraft design involves a tremendous appreciation of aerodynamics and allied problems. It also implies the development of reliable engines, which I could say is the heart of an aircraft The aircraft must have the necessary weapons which can be set into operation swiftly as the time involved in such operations is of the order of a fraction of a second As aircraft has a large obsolescence rate, it must be supported by a strong R & D group which helps to improve constantly the existing design It may advise even completely rejecting a previous design and starting of a new one Because of the high maintenance cost of an aircraft, simulation for training is a vital part of any air R & D activity The development of pilotless aircraft as targets to test systems would also be part of such a programme.

No defence is possible without a highly sophisticated communication system, be it for the detection of enemy aircraft, for communication with other sea going vessels or aircraft for just plain communication required in army maneouvres Electronics has progressed enormously in the last few years and has changed the whole concept of communication One of the important needs in warfare is the identification of an enemy or friend either in the air or on the ground and electronics has done much to solve this vital problem The coming of satellites has added an entirely new dimension to defence communication, and surveillance

Wars are unfortunately fought by human beings and as such the study of the limits of human endurance plays an important part in the work of Defence R & D The psychological and physiological behaviour of personnel either deep in a submarine or high up in the air travelling at a speed much faster than sound requires a greater study especially in Indian conditions and sociological background.

There are several other problems in a defence effort such as the development of various materials, e.g , chemicals, plastics, etc , preservation of food, the behaviour of snow avalanches especially in the border areas and so on The list given here is a small one selected from a very large number and I mention these in passing purely for the sake of giving you an idea of the wide variety of disciplines involved

Material Development

The greatest importance in any R & D effort in defence is the development of new materials particularly of metallurgical value It is required as armour of a tank, as various components of a ship or structural material of the aircraft where it undergoes tremendous stresses and strains in flight. In all this, the search for new alloys will go on. This search is an exciting field, since in recent years great advances have been made in the understanding of solid state structure. We can even say that now-a-days alloys can be tailor-made to any particular requirement. However, the elastic and plastic behaviour of materials and alloys finally set a limit to this. The engineering behaviour of any materials may be appropriately described by a characteristic stress-strain relation and the corresponding stress-strain curve, which possesses many limiting points, each limiting point describing a different behaviour of the material A typical stress-strain curve will appear as Fig 1

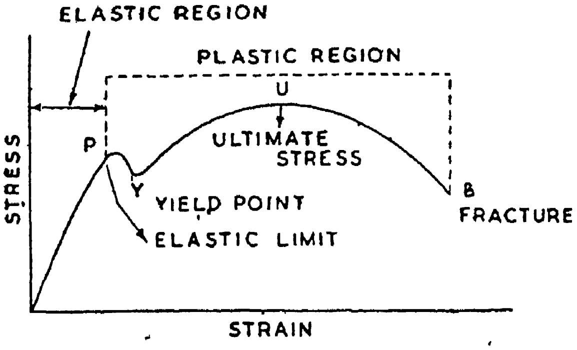

FIG. 1. A typical stress strain curve

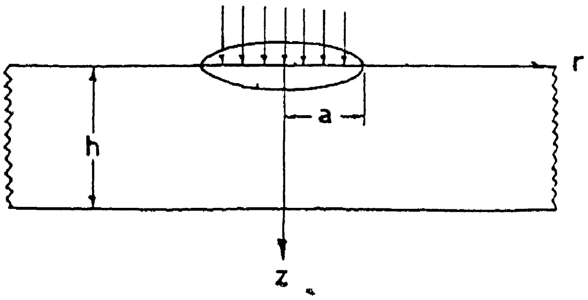

Fig 2, Loading

Here point *P* represents the limit of the linear behaviour of the material Within this limit, if the load is withdrawn from the material, it recovers its original shape

Beyond *P*, the curve bends to another limiting point *Y* which represents the yield-point stress At this stage the plastic flow sets in. Hereafter, any unloading and reloading will have different values for the yield limits. The upper limit of these yield points is denoted by *U*, the ultimate stress The material cannot stand loading beyond this limit. Point *B* corresponds to the post effects of creep etc., where the fracture takes place.

As another example of the limit set to materials by purely physical considerations, we consider the case of fracture of an armour plate of a tank It is known that fracture by spalling or scabbing takes place in an armour plate when a reflection of an induced compressional wave leads to intense tensile stresses

In a simple model loading of a plate by an explosive pulse p exp $(-\sigma t)$ over an area of a circle with radius a and plate thickness h, we obtain an approximation to the scab surface by finding the locus of the points at which the principal stress

$$S_1 = -\Sigma, \text{ the tensile limit}$$

In an accurate evaluation this locus takes the form

$$(\Sigma/P) = 1 - \exp\left\{-\frac{2\sigma}{c_1}(h-z)\right\} \text{ edge wave contributions}$$

$$(c_1 = \text{velocity of compressional wave}),$$

where the last term will be a function of both the cylindrical coordinates r and z The following figures show the relevant schematic results (Figs 2, 3a, b & 4):

Calculations for a material and loading governed by

$P = 3\Sigma$, $a = 4$ inches, $h = 3$ inches, $p =$ 0 283/lb/in ,

$c_1 = 19500$ ft/sec, $c_2 = 10200$ ft/sec and $\Sigma =$ 56800 psi

with σ so chosen that the maximum height of the scab is given to be say 0·75 inch which means that

$$-\frac{c_1}{2\sigma}\log\left(1 - \frac{\Sigma}{P}\right) = 0\ 75$$

We obtain for the primary scab the parameters;

Mass of scab = 3·5 lbs.
Velocity = 263 ft/sec.

These are reasonable figures compared with observation

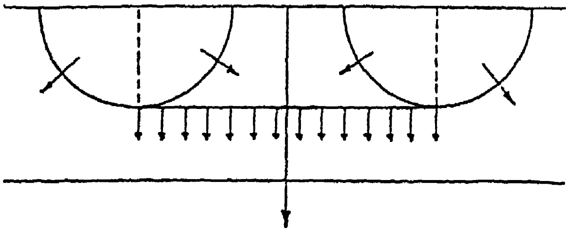

FIG. 3 (a). Progress of wavefronts before reflection

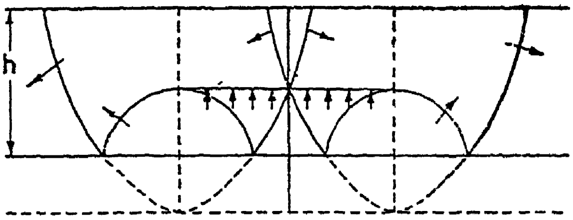

FIG. 3 (b). Progress of wavefronts after reflection

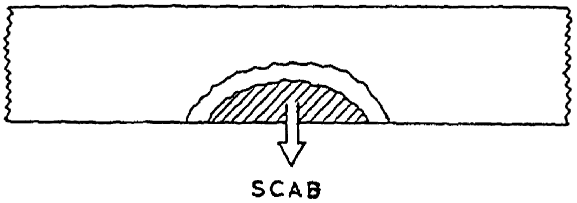

FIG. 4. A typical scab

Armaments

In recent years, new developments in the field of armaments have been in the fields of rockets and missiles I do not refer to the various developments in the more conventional armaments for lack of time. Now-a-days, practically all types of weapon carriers are equipped with rockets or missiles—be they guided or otherwise The missile could be from surface-to surface, surface-to-air, air-to-surface or air-to-air

The five major components of any missile are airframe, propulsion system, guidance and control warhead and power supply, each of which can be developed only within certain scientific limits and limitations. The scientific limits play an important role in the overall design of the missile system since the performance characteristics of the various components of the missile system are mutually interdependent; the limits and limitations of each component are further enhanced when they are developed into an integrated system For example, the size of the guidance equipment affects the size of the airframe. Increased airframe size results in greater weight and drag, which in turn raises the thrust, weight and size of the propulsion unit and further increases the gross weight But greater gross weight demands larger aerodynamic forces so that the required manoeuvrability may be maintained Greater aerodynamic forces are obtained by increasing the size of the wings, thus further increasing the gross weight This expanding process will continue until some compromise is achieved; but a satisfactory solution is not likely to be reached unless the limitations on the various characteristics of each pertinent component are studied separately and jointly.

Besides these scientific limits, the military requirement of the missile system also sets an upper and a lower limit on its design parameters The upper and the lower limits are the 'desired level' and the 'minimum acceptable level' of performance The desired level represents the best estimate of what the military planners believe is necessary to achieve unquestioned military superiority in a given area of interest whereas the minimum acceptable level represents a capability which military planners believe is still useful enough to justify the weapon system cost

The military and the scientific requirements of a missile system set the limits on its various design parameters such as its effectiveness as a weapon, manoeuvrability, firing rate, reliability, missile size and weight, combustion characteristics of the propulsion system, cost, safety, etc. To illustrate on this point, I cite a few examples for the limits on the combustion characteristics of a solid propellant rocket.

There are some special combustion properties which sometimes impose major limitations on rocket design. Such characteristics as the combustion limit, pressure limit and temperature limits are considered below

(i) *Combustion Limit*· If a number of rockets identical except for the exhaust nozzle throat diameter are fired, a graph such as the following can be plotted showing the chamber pressure as a function of the throat diameter (Fig 5) It is found, as might be expected, that the pressure decreases as the throat diameter increases. However, when a certain throat diameter is exceeded, the chamber pressure is found to be far below the pressure predicted from an extrapolation of the high pressure portion of the curve The pressure corresponding to this critical diameter is called the combustion limit Thus it appears that a given propellant cannot be used at an arbitrarily low pressure above the combustion limit if reproducible performance from unit to unit is to be obtained When low overall rocket weight is desirable a high combustion limit is a serious disadvantage, since the weight of the walls of the combustion chamber is essentially proportional to its volume and to the design chamber pressure

The combustion limit of some extruded double base propellants is about 500 lb/in^2; that of cast asphalt-potassium perchlorate propellants about 1000 lb/in^2 The composite propellants have a combustion limit not exceeding 100 lb/in^2 The combustion limit of the straight nitrocellulose propellants frequently used in guns exceeds 5000 lb/in^2. Therefore, N C. propellants are not suitable for rockets

(ii) *Pressure Limit:* Some propellants may safely be used only below a critical chamber pressure, this pressure being

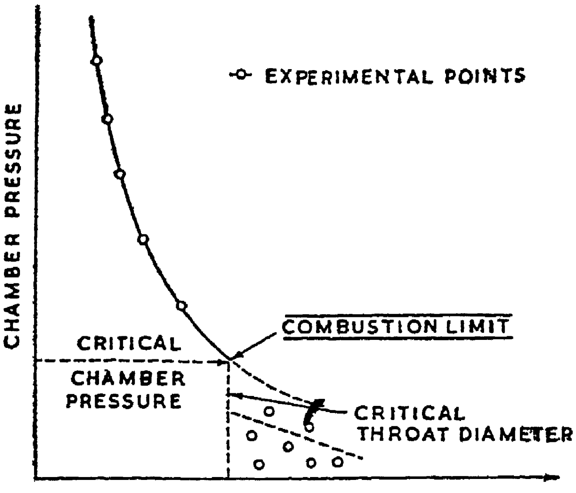

Fig. 5

called the pressure limit. If the pressure limit is exceeded, the propellant burns in a violent and unpredictable manner Brittle propellants with a granular structure are particularly subject to this effect For most of the commonly used rocket propellants, the pressure limit exceeds 5000 lb/in^2 and therefore, does not constitute a problem in rocket unit design

It is observed that, when the pressure in a rocket motor decreases below a certain critical value, the chamber pressure may fall suddenly to atmospheric and the charge ceases to burn At times, however, the charge reignites after a delay lasting from a fraction of a second to many seconds and a new period of normal burning follows. This cycle may be repeated a number of times, leading to a series of explosions or 'chuffs'.

(*iii*) *Temperature Limits:* Special limitations on the temperature range within which a rocket may be used are sometimes introduced by a change of mechanical properties of the propellant with temperature. Certain types of propellants, those having thermoplastic fuels, may soften and deform sufficiently when stored at high temperature so that an abnormally large burning area is exposed Upon ignition, the resulting high chamber pressure may cause failure of the unit Some double-base propellants may soften sufficiently at high temperatures so that the large pressure gradient along the charge which is present in radial burning units, may cause the charge to break up, exposing a large burning area, leading to failure of the unit At sufficiently low temperatures, some propellants may become so brittle that they shatter upon ignition of the charge The large burning area exposed in a failure of this kind may lead to a violent explosion Improvement of temperature limits is a continuing task in propellant development

Besides these limits, there are various others which are required to be set for a stable burning of the propellant These limits are due to erosive burning, resonant burning, etc If these limits are not observed, the propellant burning either stops, thus causing a rocket failure or the rocket blows off It is not possible to consider these topics here because of their specialized nature

Aircraft

The aircraft, considered as a rigid body flying through the airspace, moves along paths that are determined by the aircraft's inertia characteristics, the attraction from the earth's gravitational field, the propulsive forces generated by its power plant, and the aerodynamic forces and moments created on it because of the reaction between it and the air through which it moves The forces and moments created on the aircraft are functions of the velocity of the aircraft, density of the air through which it flies, the geometry of the aircraft and finally the angle that the relative wind makes with the aircraft.

The paths along which the aircraft can

fly in the airspace are limited by the aerodynamic characteristics of the aircraft, its propulsive system and the structural strength of the airframe These limitations indicate the maximum performance and manoeuvrability of the aircraft. If the aircraft is to realize maximum utilities, it must be safely controllable by the pilot to these limits without exceeding his strength and without requiring acrobatic abilities on his part

If the aircraft is to fly steadily along any arbitary flight path within its aerodynamic or strength limitations, the forces acting on it must be in static equilibrium if the path is a straight one and in dynamic equilibrium if the flight path is curved or accelerated in any way The four fundamental forces controlling the equilibrium of the aircraft are the weight, lift, drag and thrust

For the given shape, size and velocity of the airplane and the given properties of surrounding air (density, viscosity, elasticity and turbulence), there is an upper limit on the lift and a lower limit on the drag Similarly, for a given propulsive system and its efficiency there is an upper limit on the maximum thrust, that can be attained The efficiency of the propulsive system, of course sets an upper limit on the thrust, produced per unit of fuel consumption The limits on the lift, drag and thrust forces in turn set the limits on the speed, rate of climb, time to climb, range and take-off of the airplane. I shall now touch upon some of the limits which a designer comes across in the study of the dynamics of an aircraft

For the level flight of an aircraft, the weight has to be balanced by the lift The lift is dependent upon the velocity; therefore, there is a minimum speed that the aircraft must have before it can take-off This minimum speed demands long runways. Since long runways cannot be provided for many missions particularly in defence, the problem has been tackled in two different ways. Firstly, helicopters were invented where the lift is provided by the propellar itself. But these propellars cannot provide too much power because of the aerodynamic limitations and hence the speed of a helicopter is limited The other method for short runways led to the development of STOL (Short take-off and landing), VTOL (Vertical take-off and landing) and JATO (Jet assisted take-off) types of aircrafts

When the aircraft manoeuvres, the centrifugal forces, so set up, put an extra load on the aircraft structure For tighter turns, therefore, the aircraft structure has to be stronger The strength of the structure of any particular aircraft, therefore, sets an upper limit for the manoeuvrability of the aircraft Further, the tighter turns will put extra loads on the pilot also Therefore, the physical capability of a pilot to withstand such loads sets an upper limit to the manoeuvrability of the aircraft and lead to the development of Anti *g* suits

Aircraft engine depends upon the air-supply for its working As we go higher, the air becomes rarer setting a ceiling height to the proper functioning of any aircraft engine Thus, there is a limit of height to which any aircraft can go Besides this, since the fuel capacity of any aircraft is limited, the total distance which may be covered by the aircraft or the total number of flying hours without refuelling gets restricted

Communications

The two most important defence communication systems are a radar and a sonar which respectively use the radio waves and the sound waves as the means of communication. The ultimate limits on the communication speeds of radar and sonar are set by the speeds of radio waves, velocity of light and sound waves respectively. It is almost impossible to achieve these limits because of several other important constraints. In weapon system, a radar or a sonar works in combination with other system elements such as human operators, the carrying vehicle (ship, aircraft or missile) and its associated propulsion, navigation, armament, flight control, support and data processing systems. The limitations of these system components, in fact, determine the limits of achievable communication speeds

The operational requirements and the technical feasibility of a communication system (radar or sonar) will set the limits on such specifications as its range, coverage angle, information accuracy, system reliability, information handling, transfer and display, etc

An idea about some of the limits can be obtained from the case of radar system sampling frequencies (transmitted bandwidth, transmission periodicity and angular scanning frequency) which set limits on the resolution element size and the total unambiguous measurement interval of each coordinate—range, angles and velocities. For example, the transmitted bandwidth, which determines the rate at which radar system can collect pieces of range information, sets a lower limit on the width of the range resolution element of the radar. The transmission periodicity, which is defined as the fundamental repetition frequency of the radar signal, puts upper limits on the unambiguous range interval, unambiguous relative velocity interval and the scanning frequency The angular scanning frequency, which defines the minimum signal bandwidth, puts a lower limit on the velocity resolution element

One of the most formidable limitations to the usefulness of a radar is imposed by 'clutter'. Often a radar system sees too much, rather than too little, the picture is confused by unwanted echoes, or clutter This can be made up of echoes from surrounding objects on the ground like hills, trees and buildings or echoes from the irregular surface of the sea or even of echoes from storm clouds. It is this limitation of radar which makes it difficult to track a low flying plane. Though this limitation is partially removed by doppler detection systems, the clutter problem is not eliminated completely. The reason is the doppler system is effectively applicable only to moving targets, and than only when the unwanted echoes from surroundings do not fluctuate so rapidly as to defeat the pulse-to-pulse comparison which is an essential part of the scheme Another limitation of the doppler system is set by target manoeuvres, which cause a shift in the doppler spectrum This shift in doppler spectrum causes the signal to be greatly attenuated if the target doppler transists the filter band-pass range before the filter has time to build up To avoid this situation one has to set a lower limit on the doppler filter bandwidth which turns out to be $2a^{\frac{1}{2}}$ λ where a is the acceleration and the wave length.

Though radar is very effective in air and space communications, its utility as an underwater communication system is severely limited due to the fast absorption of radio waves in water Because of this limitation of radar, the sonar is mostly used as an underwater communication system

Human Endurance

I have referred to some of the limits and limitations of technical devices used in defence Of great interest is the endurance limits of the human element, which depend upon his environment and the biological strain of adaptation to extreme conditions Man's physical strength and mental activity are at their best only within certain limits of climatic conditions and strains Beyond these limits, his efficiency lessens, while stresses and the possibility of disease increase

The major elements of climatic environment which limit human comfort and endurance can be categorized as: air temperature, humidity, air movement and solar radiation. The human endurance limits for extreme hot and cold climatic conditions are shown in Tables I and II respectively.

Table I: *Endurance limits for extreme hot climate Air temperature (°C) in relation to relative humidity and average human endurance (Normal work cloths, moderate activity, moderate air movement, men acclimatised)*

Average endurance (Min)	Relative humidity (%)		
	20	50	100 (saturated)
	°C	°C	°C
300	48·5	39 7	32 2
180	52 8	42 3	33 9
60	58 1	45 8	35 9
40	61 1	47 3	36 8
30	66 1	50 0	38 9

Table II: *Endurance limits under extreme cold climate Tolerance time in min of average Indian soldiers (light activity] in shade*

Clothing + air insulation (Clo units)	Air temperature °C		
	—40	—20	0
4 5 (Arctic clothing)	80	330	—
3 5 (Heavy winter clothing)	45	100	—
2 5 (Ordinary winter clothing)	28	43	174

Endurance limits, of course, vary from individual to individual and also depend upon the degree of acclimatization Schematically it is shown in Fig. 6

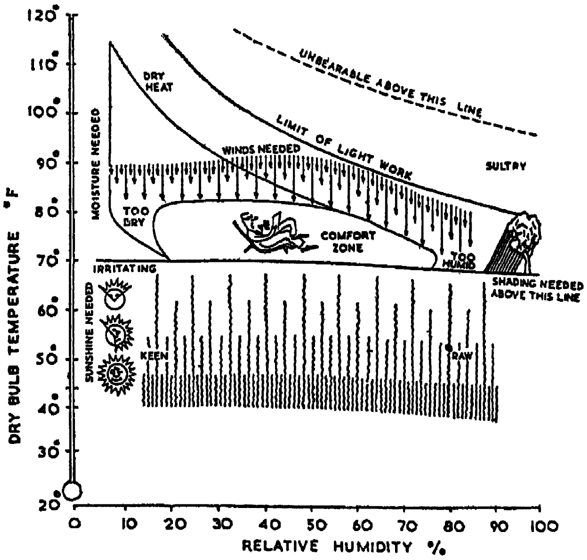

Fig. 6. Schematic bioclimatic index for moderate zone inhabitants

Atmospheric pressure puts another severe limit on human endurance Since atmospheric pressure varies with altitude, there are limits to the altitude at which exertion such as climbing can occur and there are limits to which a person may be safely carried without his exertion As for example, slight anoxia symptoms may appear at about 8,000 ft The peril of oxygen lack first arises between 10,000 and 20,000 ft The limit of consciousness while breathing pure oxygen is not known but is not far about 45,000 ft Though the modern aircraft has pressurised cabins, the above limits become very important under the conditions of war where the aircraft may be damaged and decompressurised or the pilot has to eject himself from a falling aircraft

High speeds such as are encountered in supersonic aircraft, space vehicles, etc., do not pose any problem for human endurance, so long as the velocity remains constant However pilot's endurance is very much limited when his aircraft is accelerating, decelerating, turning or manoeuvring In such situations. he encounters acceleration stress which may affect his endurance even if it lasts for a second or so These acceleration stresses are usually referred to as *g*-limits which may be positive or negative The terms positive and negative *g* are used respectively to designate whether the force is acting from head to foot or from foot to head.

Apart from the sensation of increased weight, the earliest effect of positive acceleration are related to vision A generalised veiling with apparent loss of contrast leads to a progressive impairment in the extent of the visual field. High accelerations above about 4 *g* produce further narrowing of the field until central vision is also lost, a state known as 'black out'. With further increase in the acceleration by 0 5 to 1 *g*, consciousness is also lost. The time-*g* endurance for postures in negative and positive acceleration are shown in Fig 7.

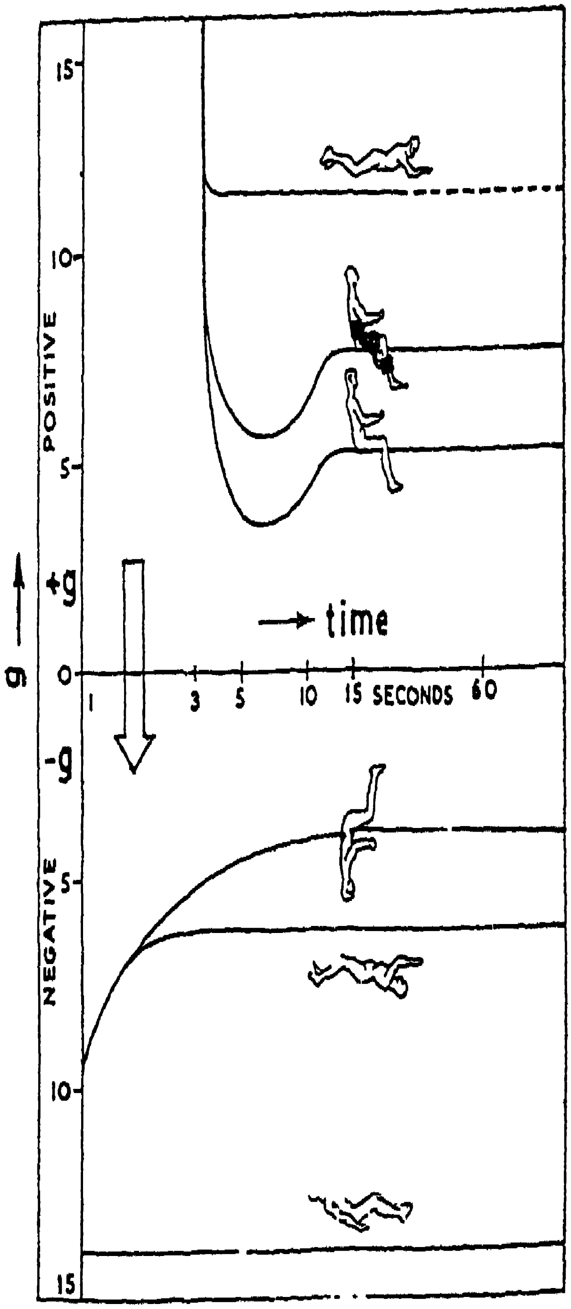

Fig. 7. Time g tolerance for [illegible] negative and positive acceleration

I have dealt on a few problems of defence, looking at them from the point of view of physical, chemical and biological limits. For obvious reasons, I have not dealt with nuclear weapons as they form a class of ultimate weapons of destruction Hans Bethe wrote on the problems of the use of anti-ballistic missiles in the *Scientific American* of 1968 I would refer you to this paper for more details

Defence Science requires the help of all laboratories and industry in the country For this collaborative effort to be effective, the problems have to be clearly identified If considered from a point of view of basic limits, there is no question of secrecy or classification and our Raksha Mantri has often stated that a considerable part of defence is unnecessarily classified With this attitude, it should be possible for more scientists and laboratories to volunteer to play a positive role in the indigenous design and development of defence equipment for the country This would be a great contribution to the Nation and a more economic way of looking at the defence effort.

Professor Vulimiri Ramalingaswami, FNA*

(Elected to the Fellowship 1973, President, 1979-80)

Professor V Ramalingaswami, Director-General, Indian Council of Medical Research, was born on 8 August, 1921 at Sri Kakulam, Andhra Pradesh. He was awarded the DSc degree of the Oxford University in 1967. He was Professor of Pathology, All India Institute of Medical Sciences, New Delhi (1957-79); Director, All India Institute of Medical Sciences, New Delhi (1969-79). He is a Fellow, Royal College of Physicians, London and Royal College of Pathologists, London, Member, Pathological Society of Great Britain, Ireland; International Academy of Pathology, USA, Nutrition Society of Great Britain, Indian Association of Pathologists and Microbiologists and Indian Association for the Advancement of Medical Education. He was awarded the Hony. Doctorate in Medicine from Karolinska Institute, Stockholm, Sweden (1974), Jawaharlal Nehru Memorial Lecturership New Delhi (1975), Jaque Parisot Lecturership of the WHO, Geneva (1975), Leon Bernard Foundation Award, World Health Organisation, Geneva (1976), J C Bose Memorial Lecturership, Indian National Science Academy, New Delhi (1978), Rameshwar Das Birla National Award (1980).

Professor Ramalingaswami described the syndrome of Protein-Energy Malnutrition in young growing children and elucidated its pathology and pathogenesis, reproduced the human disease in the non-human primate model and studied the patho-physiology of this form of malnutrition including its effects upon immunological reactivity and cell proliferation kinetics; identified the aetiology of *Himalayan endemic goitre* and demonstrated its prevention by the use of iodated salt in the Kangra Valley (HP); described the essential pathology of the liver in *Indian Childhood Cirrhosis* and identified a new syndrome of portal hypertension masquerading as cirrhosis of the liver but with better prognosis and discovered its essential pathology, identified the major aetiological factors of *Nutritional Anaemia* as one of iron deficiency and demonstrated its value in the prevention of nutritional anaemia in pregnancy and has made significant contributions to the reorientation of *medical education* to suit the health needs of developing countries

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**Address.* Director General, Indian Council of Medical Research, Ansari Nagar, New Delhi 110 029.

HEALTH AND FAMILY PLANNING—ISSUES IN THE EIGHTIES

V RAMALINGASWAMI

(delivered at Calcutta 1980)

The Present Scene

THE rate of growth of our population is the most momentous issue of our times. On a rough calculation, it can be estimated that if the present rate of growth were to continue, our population would double itself in 37 years[1]. It would reach a figure of 1270 million people by the year 2015. This would represent a four-fold increase over the 1941 figure of 318 millions This increase would have taken place in a space of 74 years. Its effects on population density, adequacy of food supplies, nutrition, housing, employment, and human development and well-being as a whole, are too depressing to contemplate. It was in 1951-52 that we in India adopted a programme of planned development so as to enable each individual to develop and grow optimally and achieve his maximum genetic potential At the same time, we adopted officially family planning as an instrument of planned development.

Much has been achieved since then. Both death rates and birth rates have been coming down Life expectancy has been increasing Small-pox has been eradicated. Cholera has lost much of its fury. The expectation of life at birth improved from about 32 years during the 40's to 50 years during the 70's. A vast infrastructure for health care and family planning services has been developed. A network of Primary Health Centres and Sub-centres has been established in the rural areas. The Community Health Worker Scheme, added recently, has now taken the health infrastructure down to the village level The training of doctors, nurses and other agents of health care delivery has been taken up on an unprecedented scale. There is now on an average, taking the country as a whole, one doctor for every 4,000 of the population. In so far as family planning is concerned, the programme started as a modest effort in the early 50's to provide advice to those who sought such an advice but the programme gained momentum with successive Five-Year Plans so that the Fourth Five-Year Plan adopted a demographic target of bringing down the birth rate from an estimated 38 per thousand to about 25 per thousand by the end of the Fifth Plan.

Despite impressive progress made so far both in the field of health and family planning, failures have been many and the present situation is serious and calls for urgent attention. The rate of fall in infant mortality rate has slowed down and the rate itself still remains high for the country as a whole. Even more striking are the vast differences in infant mortality rates between different parts of India, ranging from 165 per thousand live births in the rural areas of UP to 55 in the rural areas of Kerala. The outreach of services to the most vulnerable segments of the population and to outlaying areas is still very unsatisfactory. The imbalances between curative and preventive services continue. There is considerable distortion of health manpower structure and there is still a great deal of over-centralisation of authority and compartmentalisation of services.

As against a target of achieving a birth rate of 25 per thousand by the end of Fifth Plan, the Plan ended with the birth rate of 33 and the birth rate came down only by six points over the preceding 9 years. The revised target is to bring down the birth rate to 30 per thousand by 1983. This would involve an increase in the proportion of eligible couples protected from 24 per cent to 36 per cent. The presently estimated rate of growth of population is about 1·82 per cent per annum as against a rate of 2·24 per cent during the 60's. The situation is further compounded by the fact that even if we succeed in implementing a more vigorous family planning programme, a sharp increase in the age group 15 to 59 years from about 54 per cent in 1978 to about 59 per cent in 1991 seems to be inevitable. This structural change imposes considerable strain on employment and will also result in an increase in the population in the reproductive age group—an increase which is faster than the rate of growth of population in general, thus carrying over a substantial demographic momentum. No matter what we do, more population is in store for us up to the end of this century.

A Long-Term Programme

It is obvious that we should plan for a long-term programme aiming at a stationary population at the lowest possible level A net reproduction rate of unity should be achieved in the minimum amount of time as the Working Group on Population Policy of the Planning Commission (1979) has recently suggested This could be achieved by the year 2,000. A net reproduction rate of 1 means that on an average a woman will be replaced by just one daughter and the two-child-family will be the norm in the society. It is estimated that by the year 2000, life expectancy for both males and females will be in the neighbourhood of 64 or 65 years How is this goal to be achieved?

First and foremost, the concept of family planning should permeate all activities of Government and voluntary organisations and all forms of safe and effective contraception shall be promoted depending upon the choice of each family. The inseparability of family planning from health services in general, especially from maternal and child health care, should be realised. Legislation of age at marriage, women's education, and women's status in society, population education both for adults and in schools and universities, activities designed to enhance motivation of couples and linking of financial grants to States with contraceptive performance are some of the known strategies that could be implemented more effectively in the future.

Health Risks of High Fertility

Family health and family planning are inseparable and mutually reinforce each other. The health risks associated with uncontrolled births are well known Both in developed and developing countries, the evidence is quite strong regarding the adverse effect upon mothers and children arising out of pregnancies that are too many and too close. High foetal losses, high prevalence of malnutrition and poor physical and possibly intellectual development, high mortality amongst mothers and infants, later development of cancer of the cervix of the uterus in mothers, are well known manifestations of high and uncontrolled fertility High infant and child mortality are compensated by excessive fertility and this acts as a vicious cycle. Pregnancies taking place too early, too often, too close and too many leave behind washed out, anaemic and crippled mothers The risk of poor childhood outcomes is high for children of very young mothers of high parity. Children in Asia and Near East born within a year of their previous sibling are 2-4 times as likely to die as children born 3 or more years after previous birth[2]. A short birth interval and high parity are detrimental to the health of the mother and child Low maternal attention, increased crowding and poor hygienic conditions are accompaniments of high fertility in poor communities There is thus *a health rationale for family planning* even if one does not consider the much wider *development rationale.* It would appear that *one of the surest ways of retarding the development of a nation is to allow population growth to proceed unchecked.* Public health and public nutrition are best served by an effective programme of family planning. Family planning should be regarded as a part and parcel of good quality health care particularly those services aimed at reducing the rate of maternal and child mortality and morbidity. We in our country have adopted this policy now and given up the concept of spreading family planning through uni-purpose, family planning activities There is, however, a potential danger involved in this which must be clearly perceived and corrective actions taken. If family planning is made an essential component of maternal and child care services and if the maternal and child care services themselves are not properly developed, the family planning programme will also go down the drain. It is, therefore, of the utmost importance that health care delivery facilities particularly for mothers and children are developed rapidly. *The concept of continuity of care should be generated and the positioning of services as close to the people as possible should be ensured* Family planning services run solely as such, remained isolated. They must be combined with nutrition, health, education, and other types of developmental activities at the village level.

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[2] Omran, AR, and Standley, CC (Eds,1976). *Family Formation Patterns and Health, an International Collaborative Study in India, Iran, Lebanon, Philippines and Turkey.* World Health Organisation, Geneva.

Integration of Health and Family Planning Services

The central hypothesis in our family planning strategy is that success in family planning is best achieved *economically, rapidly and enduringly through the provision of an integrated, comprehensive health and family planning service* at the sub-centre and village level. Several experiences have shown that in the Indian context this is indeed a valid hypothesis. I have often said that the triad of malnutrition, communicable diseases and uncontrolled fertility constitute the sub-stratum of most of tropical pathology. These factors need to be understood and their inter-relationship carefully evaluated if we are to design an appropriate strategy for generating continued motivation for family planning. Perception about chances for child survival is basic to generation of positive attitudes towards family planning. Such a perception leads to motivation for family planning if advice and a wide variety of contraceptive services are available readily. But as I said earlier, *it would be counter productive, indeed, self-defeating, if the vast network of family planning services are anchored around weak and tottering public health stations, which remain aloof and alienated from the people* The health services must fulfil the daily needs of people living in rural areas and take care of illnesses of people in their homes and farms—a system of medical and environmental care that is given within the social matrix of communities where illnesses are dealt with at their origin The reality is that sicknesses exist in abundance It is through providing an effective medical care programme to the obviously sick that bridges can be established for preventive work in the future and for generating health consciousness as a way of life of people It is quite possible that the treatment and rehabilitation of sick children with marasmus or saving children with meningitis that would generate confidence and *provide a window to the family planning programme*

The Auxiliary Nurse Midwife

The Auxiliary Nurse Midwife (ANM), now called Female Basic Health Worker at the sub-centre together with the indigenous *Dai* at the village level, supported by the Physician at the Primary Health Centre constitutes the corner stone of maternal and child welfare services and of the family planning programme. The ANM and the indigenous *Dai* acting in a complementary fashion (but not in a competitive fashion) provide a basic mechanism for improved rural and maternal child health care. It is the training of the ANM and the *Dai* that is of paramount importance for the success of the family planning programme. A health educator, a rudimentary physician, a social worker, a preventive person, all compounded into one is this ANM. She is the person concerned with the vital events from the beginning of life to the time, when the child is able to go to school.

The International Year of the Child (IYC) has come and gone. If the IYC and the Alma Ata Declaration are not to be mockeries, we need *to develop forthwith a framework for systematic and continuing action on behalf of mothers and children*—action at national, local, and intermediate levels, action to *bring about lasting improvements in the services for mothers and children.* The child is linked to the mother genetically and socially. The mother and child constitute a sub-unit of the family Forces deleterious to child health and child welfare produce diverse effects. These forces need to be tackled on a multiple front involving economic and social development planning in addition to purely sectoral programmes of maternal and child health. We need a frame-work *for a spectrum of social development* if we are to tackle the problem of child health and open a *chapter of family planning becoming a way of life of the people* A horizontal approach cutting across sectoral programmes for multiple health and family planning outcomes is necessary This may not preclude altogether the adoption of a vertical approach where appropriate technology exists and a high cost benefit ratio is obvious, or where an acutely felt need by the people can be fulfilled.

Contraceptive Technologies of the Future

The demographic irrationality of our times has to be tackled both on scientific and social fronts. Population policies are not a numbers game but a question of quality of life of the present and the future generations. In so far as technology itself is concerned, we need a *more appropriate technology—"a low cost technology aimed at helping to meet the most basic needs of the poorest people in the world."* The technology itself must sub-serve the basic aims of family planning in the best interests of the mother, child and society. There is already a wide range of choices that are available for family planning. By using the existing technologies in a purposeful manner, sevral countries have shown that in spite of their poverty and underdevelopment, they can bring down birth rates over a relatively short period of time in a significant manner. So also the health status of the population can be improved substantially by an imaginative application of existing knowledge and technologies through political will. *It is not so much more effective contraception we are in need of as more acceptable and more continuous contraception.* A judicious mixture of the use of specific contraceptive technologies within the framework of Primary Health Care and overall developmental efforts is what we should aim at.

What is known in the field of contraception cannot be fully applied because of deficiencies in our delivery strategies. The irony is that *there are millions upon millions of men and women who wish to limit the number of their children* but who, for a variety of reasons, are unable to utilise the available technologies

There are those who argue that we possess adequate technology for the control of fertility today and that all we need to do is to systematically apply those technologies There are others who argue that there are many serious deficiencies in our knowledge of the fundamental aspects of conception and transmission of life, of the mode of action of contraceptive agents and of the long-term sequelae of contraceptive agents. They say that we need to do more research to evolve better, safer, and more effective contraceptive agents As usual, the truth lies in between these positions It is no doubt true that we possess today some effective methods of contraception which, if applied with a political and social will, can produce significant results in the control of human fertility. It is also true, however, that continuing rates are low, that side-effects are many and that there may even be significant metabolic consquences. The need for research on the effects of contraceptive agents on the malnourished and parasite-ridden populations of developing countries is particularly clear.

What is needed is *something that works, something that is easily accessible, of low cost, is long-acting and is reversible.* Whatever method is developed, *preservation of privacy in a village home setting,* should be regarded as an essential criterion. The search of choices needs to be broadened and it is not fully appreciated that even for a single person, variety of effective contraceptives needs to be offered which are appropriate to each phase of a woman's child-bearing cycle The use of setting must be kept constantly in mind The environment of maternal and child health services is suitable for provision of these services *in a kind and humane manner.*

The research canvas for the future development of contraceptive technology is very wide but the full picture is as yet not clear. At present, it takes 15 years or more to develop a new fertility regulating agent The question of short-term and long-term toxicity, ethical considerations involving the use of new drugs and devices on human subjects, the costs involved often running into several million dollars for producing a single agent, all these factors need to be kept in focus when one thinks of new contraceptive technologies. Those that are to be used on a large scale at the end of this century should already be in the pipeline today What then are the prospects? I am not crystal gazing but along with Dr Egon Diczfalusy[3], I would reflect briefly upon the future possibilities in contraception. *Oral contraceptives in the form of combination pills can and do give adequate contraceptive protection if taken regularly.* During the next decade, a major development that can be foreseen in this field is to obtain more objective and precise estimate of the relative risks in various population groups with special reference to tumours of the breast, uterus and liver, thromboembolic complications and increase in blood pressure. We also expect to have more concrete information on the metabolic alterations in the carbohydrate, fat, mineral and vitamin metabolism following long-term use of oral contraceptives We would have more data on the effect of these pills on lactation and transfer of steroids to the infant through mother's milk. The inter-relationship between oral contraceptives, pre-existing malnutrition and various endemic parasitic diseases should be clarified.

With regard to *long-acting contraceptive methods*, we expect to have a better understanding of the bleeding problems associated with long-term injectable contraceptive

The decade of 1980s could see the introduction of *a second generation of medicated intrauterine devices (IUDs)* which would reduce menstrual blood loss, intermenstrual bleeding, ectopic pregnancies, pains and expulsions High priority would be given to develop a special *post-placental device* with can be inserted immediately after the delivery of the placenta This, in fact, is a problem in our post-partum programme which should receive the highest priority

With regard *to abstention through the use of rhythm methods*, further progress would lie in a better understanding of the relation ship of various hormonal parameters with the exact time of ovulation It is not unlikely that a simple, "do it yourself" enzyme immuno-assay kit of the dip stick type may become available to assess more correctly the predictability of the forthcoming ovulation in advance by a minimum of 3-4 days.

In so far as the *so-called menses inducers* are concerned, it is likely that the intra-nasal administration of hormonal preparations such as various LH-RH analogues and steroids may turn out to be as suitable as vaginal suppositories releasing prostaglandin analogues for this purpose. It would, of course be a matter of the highest priority if orally active prostaglandin pills could be developed.

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[3] Diczfalusy, E (1979) Future methods of fertility regulation. *Int. J. Gynaec. Obstel.*, **16**, 571-578.

A revival of interest in agents derived from *indigenous and traditional systems of medicine* which act orally as uterotonic agents and thus as menses inducers, can be seen at present time.

One of the important features of a favourable contraceptive technology today is that it focuses largely on the female A suitable method for male contraception needs to be developed and this depends upon our understanding of male reproductive biology. Perhaps, there will be a major shift in our research from compounds that inhibit spermatogenesis to those compounds which interfere with sperm maturation, metabolism and motility. New synthetic steroids which have specific spermiostatic effect and certain halogenated sugars which interfere with sperm metabolism may turn out to be the likely candidates

With regard to anti-pregnancy vaccine, more research on toxicological aspects of this mode of delivering contraception would be done More knowledge would be available for a better understanding of the variation of antibody titres as well as duration of effect and its reversibility.

The decade of eigthties should witness *improvements in the surgical and chemical techniques* for sterilization as well as improved availability of reversible methods

When all this is done, there will still remain the problem of our ability to utilise the new technologies in a socially and culturally acceptable manner The reductionist approach of science and specialisation are essential for progress, but disease is often multifactorial. Our precious laboratory findings must be integrated into a holistic framework. Biomedical and socio-medical research must develop increasing collaboration It is futile to quib over basic and applied research. The future lies in broadening the horizon of inter-play of scientific and human experiences and of trans-disciplinary synthesis As I said recently at a Congress on Advances in Contraceptive Technology (1978), what we need is a *contraceptive bicycle* that can penetrate rural areas and reach the homes and farms of people, rather than a *contraceptive Cadillac* that has to remain largely on the highways

MODERN BIOLOGY AND MEDICAL ADVANCE

V Ramalingaswami

(delivered at Varanasi, 1981)

The Indian National Science Academy has taken some initiatives in the past few years for the promotion of molecular biology and its offshoots—recombinant DNA, and hybridoma technologies. I believe that these developments in modern biology hold great promise for the improvement of health conditions throughout the world, especially of the problems of communicable diseases and excessive population growth that continue to bedevil the developing countries Indeed, the possible benefits are likely to extend far beyond medicine and health into wider fields such as industrial chemistry, pharmaceutical industry, agriculture, energy production and even mining They have profound implications for the future of man

Fundamental biology has made greater strides during the past quarter of a century Our knowledge of cellular and molecular functioning is now quite profound Ruthless reductionism, the essential pathway of science, has paid handsome dividends The newer techniques of molecular biology, cell biology, genetics and immunology have played a key role Concentration on simplest models such as viruses, bacteria and cells isolated from complex organs was of strategic importance Of particular significance was the ability to separate pure populations of single species of molecules and even cells from complex and largely uninterpretable mixtures. As a result, we now have deeper insights into the structure and organisation of the constituents of life processes, of the evolution of form and function in living organisms, of differentiation of cells and of genetic polymorphism. Perhaps within this decade, we will see a much more elaborate and sophisticated picture of the chemistry of life.

The breathtaking events in molecular biology in the past few years have come sooner than anticipated Hybridoma technology is no more than five years old, and the recombinant DNA technology is no more than seven years old. It is now obvious that it is possible to reorder genetic material at will, and to grow unlimited copies of genes of humans and animals in bacteria Bacteria can be manipulated to synthesise biological materials that evolution has assigned exclusively to be made by the human species We can now say that modern biology will exert a considerable influence on the health and well-being of mankind in the years to come (Stoker 1980, Ramalingaswami 1980b)

The first intellectual bonuses—the human growth hormone, insulin and interferon

The first intellectual bonuses came when it became obvious that scarcely available substances such as human insulin and human growth hormone could be made by bacteria through the gene cloning techniques apparently in unlimited quantities. Human insulin and human growth hormone have already been made in the laboratory by the recombinant DNA technology. So also, human interferon, the glycoprotein which seems to be the key immuno-regulatory signal for the Natural Killer (NK) cell activity (Bloom 1980). The growth hormone gene was inserted into *E coli* and the bacteria were made to synthesise the hormone. This recombinant-derived human growth hormone was able to produce the same amount of growth in growth hormone-deprived animals as natural growth hormone isolated from human pituitaries. This should provide almost limitless supplies of this hormone for treating growth failure in children and perhaps also for improving the healing of wounds and fractures.

The human insulin produced by genetic engineering compares very favourably with porcine insulin that is being used in clinical practice today when tested in healthy human subjects. Insulin-producing cells have been transferred successfully from rats to mice in whom diabetes has been produced experimentally and the diabetic mice have been restored to normal

Interferon is being hailed as an extraordinarily potent substance which protects against viruses and slows down growth of cells thus offering a tool for the treatment of cancer as well It is generally regarded as the wonder drug of tomorrow. Up until now this unique protein was so scarce that it cost 150 US dollars for a single dose and 30,000 US dollars for a full course of treatment It was being produced by the traditional processes using human cell cultures. The possibility of genetically engineered bacteria producing interferon in unlimited quantities is now established Apparently the low yields have now been improved considerably. There is a spectrum of interferon proteins and a number of different genes code for them. A great deal of very careful clinical experimentation to evaluate the usefulness of interfering remains to be done. The world is waiting for the interferon story to unfold itself.

Genes and minigenes

Recent work has shown that the genes of animal viruses, and of animals including man occur in pieces spread out along the DNA. There is now a better understanding of how these genes occurring in different places are expressed. Each gene fragment, designated by Dr Gilbert, the 1980 Nobel Prize winner, as minigene probably codes for a functional part of a protein. Gene fragments probably code for specialised cell products like globin, insulin and antibodies. Gene regulation is now becoming more clearly understandable.

Monoclonal antibodies

Equally spectacular are the possibilities in the field of monoclonal antibodies produced by hybridoma technology. They have a number of uses in the diagnosis, epidemiological study, treatment and prevention of a wide variety of viral, parasitic and bacterial diseases. They would enhance organ transplantation capabilities by world-wide standardisation of tissue typing (Milstein 1980). Monoclonal antibodies would revolutionise the traditional methods of serological diagnosis and serum treatment. They would help in characterising the antigenic complexity of cell surfaces and detect differentiating antigens in a number of species.

Monoclonal antibody is a well-defined chemical reagent that can be reproduced at will, in contrast to a conventional antiserum which is a variable mixture of reagents and can never be reproduced, once the original supply has been exhausted (Milstein 1980). These antibodies can identify new surface molecules and at the same time distinguish amongst cell population The monoclonal approach to characterising differentiation antigens makes it possible to find out the stage at which an antigen is expressed. The Cascade purification method is being applied to characterise the antigenic complexity of cell surfaces (Milstein 1980).

Monoclonal antibodies are replacing conventional anti-sera in standard kits for radicimmunoassay procedures. An extraordinarily wide range of applications is envisaged including the study of receptors for hormones and neurotransmitter substances. A very major impact is likely to be exerted by the monoclonal antibodies being used as passive immunising agents for protecting against a variety of infections. They would pave the way for the development of improved vaccines. They have already proved to be of immense value in the field of malaria and have been shown to provide protection in animals against lethal challenges with malarial parasites.

Because of their extreme specificity, the monoclonal antibodies can be used to identify and purify molecules of interest in almost any field of biology (Yelton and Scharff 1980). They allow one to be able to differentiate between strains of viruses (Gerhard *et al.* 1978, Koprowski and Witker 1980). Hybridoma technology is a cell fusion technology which provides continuous antibody forming cell-lines. Hybridoma cell is produced as a result of fusing an antibody producing with a tumour cell This hybridoma cell grows and divides endlessly and all the progeny from the original hybridoma cell secrete the same pure antibody (Cape 1979). They are extremely uniform and reproducible. They have been made up to now by the mouse myeloma cells but they have just recently been reported to have been made from human cells also. These antibodies can attach themselves to important sites on cell surfaces thus acting as guided missiles. The antibodies selectively attach themselves to certain cells and can deliver a dose of destructive material to these cells. The material can be a powerful anti-cancer drug or a toxin and the rest of the body tissues and cells are not affected.

The challenge of tropical communicable diseases

It is in the control of some of the intractable tropical communicable diseases that I believe lies the real challenge to molecular biology. Confronted as we are with a situation in which: a) *Plasmodium falciparum*, the most dangerous form of malarial parasite, is resistant to the most widely used anti-malarial—chloroquine; *b*) several species of mosquitoes that transmit malaria are resistant to the commonly used insecticides on which we are dependent today for mass use; *c*) for mass control of leprosy, we depend upon only one drug 'dapsone' against which the leprosy bacillus is showing increasing evidence of resistance; and *d*) we have only one effective microfilaricidal compound, thio-carbamazine to fight filariasis—these reflect the technological despair which surrounds the whole scene of control of tropical communicable diseases especially malaria, filariasis and leprosy It is through a better understanding of the biology of these parasites and microbes that we can hope to develop new strategies and new approaches for their control We have to understand the tricks that the parasites play. How do they avoid host defences? How do they acquire drug resistance? Modern biology should enable us to attack the vulnerable sites in the life cycle of these parasites. The technologies that I have described should enable us to prepare pure parasite antigenic material Parasite genes coding for important antigens could be identified and transferred to harmless bacteria, getting the bacteria to make the antigenic material which can then be used for diagnostic as well as prophylactic purposes Modern biology should enable us to block the attachment of parasites to specific host cell membrane receptors making it difficult for them to survive and multiply A drug may be linked to a molecular carrier preferentially homing to vulnerable sites in the parasite. Drug-liposome and drug-antibody complexity offers interesting possibilities

Gene treatment

There are possibilities in the future of being able to correct at least some genetic defects through the techniques of molecular cloning Single gene errors may be correctable Sickle cell anaemia is due to a single variation in a group of genes involved in the synthesis of haemoglobin. Gene treatment is in the realm of possibility of molecular biology, but there is a long way to go from the present position to the repair of genetic defects in intact human beings Single genes have already been injected into defective living cells in culture and have cured those cells of genetic defects.

Modern biology in agriculture and industry

Genetic engineering might make it possible to increase the efficiency of photosynthesis and to improve nitrogen fixation. It may also be possible to identify genes that make plants more tolerant of saline than others The importance of this technology is obvious considering the problem of increasing salinity of our soils following irrigation The disposal of agricultural and industrial wastes could be accomplished with useful byproducts by the use of biotechnology Fermentation industry can benefit enormously by the gene splicing technology for large scale production of amino acids, nucleotides, organic acids, etc. It is possible to stitch into the DNA of industrial micro-organisms the human genes to render the microbes capable of producing vast quantities of widely needed substances (Cape 1979).

Chemical transformations in industry are normally performed at high temperatures and high pressures needing high inputs of energy The gene technologies will be able to accomplish the same thing with low energy inputs because the work can be done at room temperature and at atmospheric pressure The problem of wastes will probably be minimised in the biological production systems

Brain chemistry

There has been a quantum jump in our understanding of brain chemistry in recent years Until 10 years or so ago we were 'limping along' on a few classical neurotransmitters, and electro-physiology was the main tool for studying brain function. No doubt much has been learnt by these techniques. Today, there are literally dozens of neuro-transmitters, neuropeptides and neuro-hormones discovered which constitute the biochemical circuitry of the brain There are expectations that the endorphins and the encephalins may pave the way for a possible solution to intractable pain and drug addiction. There are hopes of a better understanding of human feelings and human behaviour, of learning and memory, of sleep and of various levels of consciousness. The brain's medicine chest has been at least partially opened and this has unfolded the brain's incredible chemical repertoire. Simultaneously, there are major advances taking place in psychotropic drug development The screening of potential psychotropic drugs has moved from the laborious animal testing, the old black box approach, to the world of molecular biology. The assay of drugs for their effects on behaviour is done on isolated brain cells The area is undoubtedly full of promise for an understanding of how the brain functions, but in terms of practical benefits to cater to the needs of 'choose your mood' society, one should not expect results around the corner (Gurin 1980).

Hepatitis B vaccine and liver cancer

I cannot let this occasion pass without referring to the developments leading to hepatitis B vaccine. The vaccine is itself the outcome of basic research in biology and clinical medicine. In October last year, a report by Dr Szmuness and his colleagues indicating the remarkable success of a carefully controlled hepatitis B vaccine trial in a high risk population of homosexuals in the United States has been regarded as a milestone in the annals of preventive medicine (Zuckerman 1980) Hepatitis B is of great public health importance in our country as well as in many developing countries It has been estimated that there are as many as 200 million people who carry the hepatitis B virus in their blood, known as chronic carriers The vaccine contains 22 mm hepatitis B surface antigen particles which are derived from the plasma of healthy carriers and inactivated with formaldehyde Infection with this virus can lead to a form of chronic liver disease including cirrhosis and there is also an association with primary liver cancer The work done by Professor N C Nayak in our country has shown the close association between primary carcinoma of the liver and the presence of hepatitis B surface antigen in nearly 100% of all cases of primary liver cancer both in our country and in Africa. The vaccine against hepatitis B can be of great value in protecting persons who constitute high risk groups against this form of hepatitis. These are persons who receive multiple blood transfusions and patients and staff working in the kidney transplantation and haemodialysis units.

There is considerable evidence to suggest that infection with hepatitis B virus is an important precursor to the development of liver cancer. There is strong geographic correlation between hepatitis B infection and liver cancer and there is also some evidence to indicate that a substantially large proportion of mothers of patients with liver cancer are chronic carriers of the hepatitis B virus The link between the hepatitis B virus infection and liver cancer has received further support from the reports published by four groups of independent workers which show that the DNA of the hepatitis B virus is integrated into the genome liver cancer cells (Journal of Virology, *33*, 795, 1980 and Nature, *286*, pp 531, 533 & 535, 1980). Although this does not prove that the virus is responsible for producing the cancer, it is once again an additional piece of evidence to support the connection between the two If reviewing all the evidence that is presented so far, hepatitis B infection is a prerequisite for the development of liver cancer subsequently, then the elimination of that infection through hepatitis B vaccine should also eliminate the development of liver cancer. Already, the 1980 Nobel Laureate Dr Gilbert of Harvard University and others working in Edinburgh and Heidelberg have reported that they have been able to insert hepatitis viral genes into bacteria and both hepatitis B surface antigen and a protein from the virus core are being produced by the bacteria.

Conclusion

The new technologies will take time to move from laboratory scale to large scale production. But from the kind of rush that one sees in this area, it can be expected that the transition from experimental to clinical level application will take place sooner than later. This is all to the good but in all this, what guarantee is there that these products for the health of man will be accessible to those in greatest need at prices that they can afford? The history of science and technology repeats itself—each major advance enhancing the dependence of developing countries upon the developed ones.

It is sometimes said that basic research and high technology are for developed countries and that appropriate technology will do for developing countries While I am second to none in upholding the importance of appropriate technology for developing countries, no country, developed or developing, can do without basic research and no sustained development is possible without it (de Duve 1980) In this particular case, India has a unique opportunity to develop a solid programme of basic research in modern biology and a whole range of skills in molecular biology to resolve some of our health problems and to speed up overall development Finally, the fast-moving events in molecular biology must be coupled with human wisdom in their application, if we are to reap the full benefits of this technology without paying a heavy price The earlier concerns about the safety of gene splicing techniques have now somewhat receded to the background, but the question of careful use of the new and powerful products available in large quantities still remains Their safety will have to be very carefully evaluated A whole range of ethical issues will have to be faced. The question of gene therapy, for example, will raise a number of such issues. Ethical guidelines in such matters are much more difficult to develop than guidelines of safety (Dickson 1980)

The new Biology cannot remain isolated from social issues. As I said in my Annual Address last year the future lies in broadening the horizon of interplay of biomedical and socio-medical research and in transdisciplinary synthesis of science and technology with society's needs and human values in a changing world (Ramalingaswami 1980a).

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Professor Mambillikalathil Govind Kumar Menon, FNA*

(*Elected to the Fellowship, 1970, President 1981-82*)

Professor M G K Menon, Member, Planning Commission, was born on 28th August, 1928 at Mangalore in Karnataka. He was awarded the PhD degree of the University of Bristol in 1955. Professor Menon was the Director, Tata Institute of Fundamental Research (1966-75); Chairman, Electronics Commission and Secretary to the Govt. of India, Department of Electronics (1971-78); Scientific Adviser to the Ministry for Defence, Director-General, Defence Research and Development Organisation and Secretary in the Ministry of Defence for Research and Development (1974-78), Director-General, Council of Scientific and Industrial Research (1978-81), Secretary, Department of Science and Technology, Govt. of India (1978-82), Secretary, Department of Environment, Government of India (1980-81), Chairman, CASE, Government of India (1981-82); the Chairman, Science Advisory Committee to the Cabinet. He is Fellow of the Royal Society (London), Honorary Fellow, National Academy of Sciences (India), Founder Fellow, Maharashtra Academy of Sciences, Poona and Honorary Foreign Member, American Academy of Arts and Sciences and USSR Academy of Sciences, Member, Pontifical Academy of Sciences. Professor Menon was awarded the Honorary DSc from eight Indian Universities, and IIT, Madras, Senior Award of the Royal Commission for the Exhibition of 1851 (1953-55), SS Bhatnagar Award of CSIR (1960); G. P. Chatterjee Memorial Award of ISCA (1983); Khaitan Medal of Royal Asiatic Society (1978), Kerala State Committee for Science and Technology Prize (1979) and Padma Shri (1961), Padma Bhushan (1968) and Cecil Powell Medal of the European Physical Society. He was the General President of Indian Science Congress Association, 1982.

Professor Menon demonstrated the existence of muons of varying energies, monoenergetic, high energy charged pions and electrons of varying energies, as secondaries in the decay of heavy mesons, leading to the establishment of K3 K2 and K3 modes of decay He was responsible for first demonstration of scattering phenomena involving K particles and discussion of these in the terms of the strangeness concept. He was involved in the development of high altitude balloon programme at TIFR to a point where it has now become a dependable facility for primary cosmic ray work. Significant results/observations include those on the so called multiparticle Kolar events; evidence that the Utah claims could not be correct that muons are significantly produced directly at high energies because of their apparent observation of a departure from the Sec effect; the most extensive observations of muons underground; first observation of interactions of natural neutrinos; and observation of candidate events, including high quality fully confined events suggestive of nucleon decay with a life time of 7×10^{30} years from experiment at KGF.

**Address*. (*Off.*). Member, Planning Commission, Yojna Bhawan, Parliament Street, New Delhi 110 011 (*Res.*) · 1 Motilal Nehru Road, New Delhi 110 011.

PRESIDENTIAL ADDRESS

M G K MENON

(delivered at New Delhi, October 1982)

I would like to give you a general background about what is happening in the Academy since the beginning of the year and with particular reference to what the Academy should be doing We have, of course, had the regular series of meetings for various purposes connected with our functioning including the normal Council meetings, the general meetings of the Academy, the meetings of ICSU National Committees and the meetings of all individual committees which liaise with International Unions, the meetings of Sectional Committees for recommending candidates for election to the Fellowship, as also those to be awarded the INSA Medals for Young Scientists and the various other activities of the similar nature. The Science Academy Medals for Young Scientists 1982 have been awarded to 16 scientists, the Medals announced last year were presented to 20 young scientists by the Prime Minister at the Science Congress Session on 3rd of January in Mysore In addition to the normal functioning of the Academy, I would like to speak to you this afternoon about a few other questions

We have been discussing quite extensively in our Council on the role of the Academy. You are aware of the normal activities; one which relates to the election to the Fellowship and the Foreign Fellowship; the second which relates to our liaisons with international bodies including the ICSU and all the International Unions. Associated with it is the fairly large activity of sending scientists from India abroad to the ICSU meetings. From the large list which comes up for delegations, the delegations which go for the various ICSU meetings have quite successfully been selected by the sectional committees. It is becoming increasingly more realistic that ICSU conferences cover, to a great extent, science whether it is mathematics or physics or chemistry and so on, or several biological life sciences, but they do not cover engineering sciences, they do not cover technology, they do not cover agricultural sciences, they do not cover medical sciences. In addition, there are large number of meetings now being held of a specialized thematic nature even in the pure sciences which do not come under the ICSU conferences These are very interesting, important meetings; and these should be attended. Therefore, special efforts were made to have discussions in the Department of Science and Technology to be able to send scientists to these meetings and I am glad to say now that arrangements have been made for INSA to be funded for the purpose That we are also now able to support scientists for the non-ICSU meetings. The amounts are still inadequate It is inadequate as far as INSA is concerned, inadequate as far as the Department of Science and Technology is concerned because these are the non-Plan funds and, you know, for non-Plan funds it is not very easy to expand. But a beginning has been made There is also significant support now being given to young scientists under the INSA-COSTED agreements So, what I wanted to really give you is a feeling here that INSA is now able to support and has supported this year much larger numbers on a more satisfactory basis for attending meetings abroad. This in itself is important because, I think, we have to accept the fact that science is international, great advances are taking place elsewhere and while certainly original ideas are coming up and considerable work is done in the country, it is important to know what is happening. And I would come to this a little later—the question of bridging gap between what is happening here, what is happening elsewhere. But from that angle it is particularly important that we are kept informed of this.

I would like to mention to the Fellowship that someone who goes abroad for a conference is, in some sense, privileged to have an opportunity to go to a meeting in which either he or she contributes or participates in some sense or, if nothing else, is able to listen to and appreciate the most recent developments in that particular field. It is not enough for that person to benefit personally and come back, and, therefore, do better work as an individual. It is important to communicate this to the scientific community in the country. So, we have decided that it will be incumbent on anyone who goes abroad with finances provided by INSA—and we have to be accountable in public for it—when the person comes back—to write a report. As you know, reports are written. I have here a list of them in terms of who chaired meetings and what are the titles of the sessions, then what are the programmes you have arranged, how many delegations attended. Well, that is not science, I mean, scientific. What are the highlights? What are the new developments? What is the significance to Indian science? Where do we benefit from the information derived from that meeting? What are the thrust areas on which one could concentrate? What are the dying areas in a certain sense and so on. So, we would like the reports in that form to be presented and to be then published by INSA for the benefit of the scientific community in the country. Now, this could turn out later to be a journal of some description but in the beginning we will start; and the Editors of Publications have agreed to take this up. I thought that I would mention this as a development where INSA could bring to the notice of the Indian scientific community the developments in various fields abroad.

It also related to the Basic Sciences Committee which, as you know, has been operating very well. We had our last meeting in February on 26th and 27th at the Osmania University; I was present at that meeting. Normally, of course, the purpose of that meeting is to bring together those who receive INSA grants for their schemes as well as many others concerned with various schemes in Basic Sciences and to listen to them, to interact with those who receive INSA grants and also to have some lectures from active individuals in various schemes. The meeting at Hyderabad went off very well and we have to continue to support some 112 research schemes under the Basic Sciences Training Programme, and so on. But that is a matter of detail which is contained in the Annual Report. But what I want to emphasise here is the fact that what INSA disburses is a very small amount. It is of the order of 16 lakh or so. This, in my view, is trivial if you compare it with the multi-crores which are disbursed by the other major agencies in the country. For example, CSIR has been disbursing of the order of four to five crores for its extramural activity for various things like junior and senior research fellowships, associateships, for research schemes. The Department of Science and Technology has of the order of four crores which are disbursed under the general research fund. I would not go into the details of all that the Government disburses. But, similarly, there is a so-called Science and Engineering Research Council of the Department of Science and Technology for the intensification of research in high priority areas; there has been a MAB Programme and the Environment Research Committee of the Department of Environment; there is a Board of Research of Nuclear Sciences; there is a Department of Atomic Energy; there is a Department of Space and there are programmes of ICAR, ICMR and the UGC Fellowship and one can list a huge number. Compared to this, 16 lakh of INSA is very, very small. So, what we really have in mind is that this must be used in a way where one would provide support to something which may be quite new to start with and which would later, if it becomes successful, receive support on a major basis from one of the agencies. The idea is to discern and identify well in advance, particularly from young individuals, the possible areas of thrust and growth and new creation. But we have also decided that the Basic Sciences Committee should do something more and we have taken up something which I referred to in a sense last year as an idea that we should also produce reports—state-of-the-art reports for instance—in various areas in basic sciences—which could be published—which may indicate what is happening in some of these thrust areas in the country, what is the state of research in this field elsewhere in the world, what are the techniques being used and where interdisciplinary efforts and so on are coming up today so that those who are working in the field become more aware of a sense of direction. Very often you find somebody who is well-versed in a technique, is working in some area where on account of past history and tradition and something which exists in a particular school has been proceeding along certain well-trodden paths; he could very well do something which is very much more in the frontier, important and interdisciplinary but does not do so because of just that difference in the interaction and, I think, the state-of-the-art report could do some of it. So, we have felt the need for it and, I hope that the Basic Sciences Committee will be able to do more in this regard and our Fellowship will provide support for this, namely to define the thrust areas and to define the directions in which with our capabilities we can proceed. Particularly important is to know what facilities are available where and who is working on what topic and with whom to correspond and discuss because one of the features, which is characteristic of international science today, is the manner in which interaction takes place. Of course, we must remember that academies or societies were originally constituted for the very basic purpose of interaction. The oldest among them was the Athens Academy of Plato which in a certain sense has continued to be in existence since then.

But societies have been older than the scientific societies. The Royal Society, though certainly not the oldest, was started with the purpose to bring together like-minded people who could talk to each other and discuss, demonstrate experiments and interact. This interaction, of course, today is not dependent on academies alone. We have talked about the conferences under ICSU and non-ICSU and variety of manners in which interaction takes place, as of course elsewhere in the world, through publication of journals and so on There are so many meetings, there are telephonic conversations and the like It is very important that we bring about much greater interaction, develop not only a cohesion here in the scientific community in the country but also produce new ideas and new capabilities which may exist in the sense that there may be an individual in the country who knows a mathematical technique or who can handle an equipment in a certain way which is all that is necessary to transform something you are doing from being ordinary to being a break-through and, therefore, there is a need to do this rather than purely routine publication of papers which we have been doing for a long time

The other point I wanted to make is, I think, important I felt, coming to this Academy that whereas we have our grounds and buildings, they really are not what they should be for a premier Academy in sciences of this country. We ought to do something very much better. There have been schemes—and I see Dr. Pal is here who has gone through these schemes for a major building and so on—but they have not fructified or materialized uptil now. Costs are rather high. There have been problems for getting funds for it. So, I felt, in the first instance, we should make sure that whatever we have which consists basically of two buildings—this one here where we are sitting and the one there where the auditorium is as well as where some accommodation is available for the Fellowship—be brought up in standard. Now, we have gone through a succession of discourses with the Building Committee and the architect who is supervising the work and we have taken a decision to proceed with a considerable renovation which would enable considerable improvement as well in the auditorium and reception areas.

We have also made very many changes. I wouldn't go into the details of this. But if any of you walks up in the administrative area of this building, you will find the place cluttered up like the records offices of the Government. It is certainly unsatisfactory for an Academy concerned with science. So, we have decided to remodel it into proper cubicles, office spaces, stock rooms and so on and do the same thing on the other building to increase, to a limited extent, accommodation and also to have the Executive Secretary stay on the premises because, I think, it is important from the view-point of control and management of this area. Well, these changes you would notice, because they are all going to be completed as from now, in a period of six months. These will be some changes which will certainly improve the overall appearance of the Academy.

As far as other activities are concerned, I thought, I would just mention the following. First I went—which is really speaking the first trip that I made on behalf of the Academy last month—to Rome. This was to attend the bi-centenary (200 years) of the Academia Sciences Nationale de Sciences, as they say, *de quaranta*. This is the Academy of just forty (40). You know, European academies have very restricted numbers like the French Academy, for instance, but that is obviously not restricted to science but science and humanities put together. Now, this particular Academy was founded in a very interesting way, two hundred years ago and if anybody recalls the history of Italy, you will notice that Italy did not exist then because that was when all of Italy was in the form of city states and which came under considerable domination. That is the pre-Napoleonic and post-Napoleonic period. And the concept of this Academy is very interesting. It was evolved by an engineer who was a military engineer but very good in scientific matters relating to mathematics and surveying and who decided that scientists must get together—and in fact hit on the idea of the scientists of Italy unifying before the politicians and others.

One of the very basic principles of the Academy is to publish its memoirs and to publish at least once a week through the years. They have just produced, in addition to other things, 100 memoirs starting from that period The exceedingly interesting work, particularly interesting of the early period which I happened to see, was the vast collection of original documentation of some of the pioneers coming down to more recent periods. I attended the Bi-centenary, when they had essentially a two-day symposium on 'Academies looking towards the year 2000', namely, what should the academies be doing, with presentations from a variety of academies around the world, on international cooperation and the role of the academies and many of these questions. It was a very interesting meeting, and I will try to give a brief summary in the Newsletter. But it was very, very clear that the academies will have to seriously consider their role because science has changed very, very significantly since the days when the Academy was founded, when the Royal Society was founded and, on similar basis, the French Academy, the Italian Academy, the National Academy of Sciences of USA and the INSA which is of course very much younger. The important point here is the fact that some academies, National Academy of Sciences in particular, have done very much more in a certain sense by bringing out a whole variety of documentation which is of importance both to scientific community as well as to the Government in the United States. The Royal Society also brings out as a result, particularly of its special discussion meetings which are organised, documentation of that nature and, I think, it is very important for this Academy to consider what else it should be doing in this regard.

The other important element of my visit was the two-day meeting at the Pontifical Academy of Sciences in Rome. This meeting was arranged at the instance of the Pontifical Academy to take advantage of the fact that Presidents of the Academies around the world were present in Rome at the Bi-centenary of the National Science Academy. It was a very good meeting. The principal question under discussion was that of nuclear war. I bring this to your notice because, from what I know, INSA has never discussed this question. The entire area relating to nuclear energy for peaceful purposes, its constructive aspects and so on-have been dealt with purely on a temporary basis. We have never discussed it at all as scientists—questions relating to nuclear energy. Well, the reason of this meeting is simply that the Pope has been deeply concerned about the threat of nuclear war because of the fact that there are large number of trouble spots which have repeatedly appeared on the world scene whether it happens to be Palestine or Poland, whether it is Iraq-Iran or Israel-Arab question, whether it is Lebanon and so on and so forth. There is today enormous accummulation of nuclear stockpiles in the world. It only needs a wrong decision and a miscalculation to set off and once set off, it will be an irreversible explosive situation. So, he has spoken about this notably at two places; when he visited Hiroshima and at the UNESCO Address that he gave last year. Pontifical Academy has, therefore, been concerned about the question of nuclear war. Pope was concerned about it from the viewpoint of moral, spiritual and scientific aspects. Because of this interest, the Pontifical Academy had a Working Group which has produced a documentation. I was asked to chair the Working Group and when I was in London for the Festival of India and Britain where we organised a 'Science in India Exhibition' at the Science Museum, I spent three days in chairing the drafting Group. We drafted a document which was then considered again by another meeting of Pontifical Academy in Rome—I could not attend that meeting—in June; and that document came up for consideration. After this two-day meeting on Thursday and Friday last week in Rome, we were able to draft a document which was accepted and signed by the Presidents, on behalf of the Presidents and representatives of the different Academies, except for the Chinese Academy of Sciences, though they had originally agreed to come to the meeting in Vienna in February. There was a world-wide presentation and acceptance of this document.

Now; of course, the purpose is that this is a document from the Academies. It is not a formal document because it had not been presented to INSA and INSA has not adopted it. But it is a document agreed to by the Presidents of the Academies but in their own personal capacity. But it is interesting that a document has been produced and it will not, of course, have to be used but the idea is that it might be used by religious leaders to bring about certain religious pressure on statesmen and world leaders in this regard. It is such a major question, but we have not even discussed it in the Academy.

From this sort of background, I would like to tell you a little more of what I think we ought to be doing. Apart from sending delegations abroad, we also sponsor major conferences in India—some are general assemblies, some are general conferences, others specialised conferences—and these are taking place on a regular basis. But apart from these activities which have been absolutely standard, frankly speaking, can we say that we are doing anything unique? There are other places where documents are published also. This is not something unique. What we are not doing is giving the vast amount of support that is required by the scientific community or by Government, and what we are not doing is really trying to see what science needs to be healthy and to grow meaningfully in this country. That is something we have to address ourselves to a much greater extent than we have done in the past. I must say we had a pre-meeting discussion, if I may put that way, for two hours this afternoon before we assembled here and we have had also some discussions earlier. I must bring to the notice of the Fellowship that I do not think that health and climate of science in India is satisfactory. We must understand this. I am not talking just now of technology. That is a separate matter. Then we can discuss whether we are dealing with agricultural strategies and lab-to-lab programmes, whether we are dealing with technologies, with industrial processes, import of technologies, indigenous development of technologies. That gets us into a completely different area of industrial policy, technological policy statements, which are not science. I am talking of science and science which has to be defined not in terms of support to the elements of technology but science in terms of new innovations, in terms of work in the frontiers of science and in that regard, I think, the position has not been very satisfactory. If you read the talk that I gave as President of the Indian Science Congress Association in January at Mysore, some of my thoughts are already contained in it because my entire lecture was devoted to basic sciences as an integral component of a self-reliant base of science and technology in the country. So, the entire lecture was related to the basic topic which is science, not to technological elements but basic science, and building up excellence in this country and the problems in building up excellence.

Why I mentioned that the position is not satisfactory is that we do not have today a climate in which the most brilliant are attracted to science. They may not be attracted to science abroad for other reasons, which may relate to nuclear weapons stockpiles or environmental pollution or the backlog of Vietnam and so on and so forth. But in India, the reasons are very different. In India, the reasons relate to the fact that we are not giving a sense of excitement and challenge to the younger generation to take to science as something which they must do because it is so interesting. That is not being done. That can only be done in the schools and colleges, that can only be done through books that are written; that can only be done in the universities, and our entire system there, for a variety of reasons, has run down due to lack of infrastructural support, due to extremely poor economic conditions that have been provided, due to total lack of respect provided to those who are in these positions as teachers, and finally the teaching community itself having taken upon itself many a factional and political role as a result of which it has lost the respect due to it. And furthermore, mediocrity is practised on such a scale that once you get mediocrity, it only allows more mediocrity Now, that is one part of the story; that the best are not coming to science. There are other propositions, other attractions for them into which they are flowing. The best illustration of this was in the fact that many of our Council Members pointed out that the important scientific positions in the country are Professorships and Directorships. You have to go straight to the bottom of the barrel; you have to find them who might take up science and use your greatest influence to cajole and persuade them to take that job. These should be positions which are considered reliable, respectable, and wanted as an occupation. The second aspect with regard to the scientific scene is that even those who are coming in are at the ages which are quite critical where opportunities for them are the very best. Opportunities for the mediocre are few. Opportunities for the very best are many They are the ones to be attracted. They are the ones who go out and who then do not come back and who are essentially more or less persuaded to stay there. They have to make an effort. Much of our system has become highly parochial. Universities today do not appoint anyone outside their own group. Even the theory of the "Sons of the soil" has got so limited that it has not become a free university even within the same State It has become narrow and parochial, and that is true of laboratories as well I am not blaming universities alone. It is impossible today to arrange the transfers of people from one lab to another. They do not move themselves. They are not wanted in the place of their last appointment Furthermore, the number of positions available which can be filled on easy basis is very small. The net result of all of this is that the cream of this country either does not come to science or if it comes to science, goes away rather than wanting to take up the responsibility here and do good science and to build centres of excellence. Also, on account of external influences which relate to the democratisation of procedure, legal quarrels and wrangling and so on, it has really transferred a great deal of our activity to personnel and labour handling rather than the handling of sensitive, brilliant people. I think, we have to recognize that if we do not pay attention to this soon as a scientific community, then we will get into an increasingly difficult situation with regard to having any science in the country in the decades ahead in spite of having a very large output in terms of B Scs and M Scs, in terms of much larger investments in money Real science, as one understands, relates to the frontiers. So, I think, we ought to pay serious attention to it We should look ahead and that is what I would urge the Fellowship to consider and to provide inputs to the Council so that one can do something more meaningful to build up science in this country.

Professor Arun Kumar Sharma, FNA*

(*Elected to the Fellowship 1970; President 1983-84*)

Professor A K Sharma, Professor and Programme Coordinator (Director), Centre of Advanced Study on Cell and Chromosome Research, Department of Botany, University of Calcutta, was born on December 31, 1924 at Calcutta. He was awarded the DSc degree of the Calcutta University in 1955. He was the National Lecturer (University Grants Commission) during 1977; President, Society of Cell Biology (1979-80), Genetic Association of India; Secretary, Indian Science News Association (1978); Biological Secretary (up to 1977), the Asiatic Society; President, Botanical Society of Bengal (1977-81), Indian Botanical Society, Indian Society of Cytologists and Geneticists (1976-78) and General President, Indian Science Congress (1981). He is a Fellow of the Indian Academy of Sciences and National Academy of Sciences (India). He is the recipient of SS Bhatnagar Prize 1967) of CSIR, Jawaharlal Nehru Fellowship (1972), Paul Bruhl Memorial Medal (1972) of Asiatic Society, Birbal Sahni Medal (1974) of Indian Botanical Society, First JC Bose Award (1976) of UGC, Silver Jubilee Medal (1976) of INSA and the Federation of Indian Chamber of Commerce and Industry Award (1979). He received Padma Bhushan in 1983.

Professor Sharma's principal research contributions relate to : (1) invention of new techniques for the study of *physical* and *chemical* nature of chromosomes, adopted in all centres of the world for plant, animal and human systems, the latest technique being orcein banding for repetitive DNA, (2) establishment of a new concept of speciation in vegetative plants, (3) clarification of chemical nature of plant chromosomes through techniques specially evolved for the purpose, (4) induction of division in adult nuclei through certain metabolic precursers for the study of chromosomes in relation to differentiation, (5) reorientation of angiosperm taxonomy on the basis of cytological data collected from investigation on different families, (6) establishment of a new concept of dynamism of structure and behaviour of chromosomes, both physical and chemical, in plant, animal and human systems, (7) successful utilization of embryo irradiation and *in vitro* culture for generating variability, and (8) the concept of Dynamic DNA, showing amplification, dispersion and mobility. The chemical composition of chromosomes has been shown to vary during organogenesis, differentiation and reproduction while maintaining the constancy of the basic genetic skeleton The concept is based on chemical analysis *in situ* and after extraction as well as fluorometry and biochemical assay. The value of these researches on chromosomes, in addition to their fundamental importance, lies in their utilization in agriculture, horticulture, medicine and environmental planning, analysis of problems of environmental pollution and recommendation of remedial measures.

**Address:* (*Off.*)*:* Department of Botany, University of Calcutta, 35 Ballygunge Circular Road, Calcutta 700 019.
(*Res.*)*:* Flat No. 2F2, 18/3, Gariahat Road, Calcutta 700 019.

PRESIDENTIAL ADDRESS

A K Sharma

(delivered at New Delhi, October 1983)

The annual meeting of the Academy calls for an introspection into its activities about which the president is supposed to apprise the Fellowship. If one takes into consideration the charter of the objectives of the Academy, it includes not only the culture of excellence but to a great extent also the promotion of natural knowledge and its application to problems of national welfare; coordination between the Scientific Academies and Institutions; International representation and lastly safeguarding the interest of scientists of India. With the gradual involvement of the Academy in various national activities and national problems it is also desired that as a peer body of scientists it should express its opinion on issues of national relevance for the benefit of the policy makers It is desirable to have a look at the extent to which our Academy has been striving to fulfil the charter of its objectives.

As far as the policy issues are concerned, on behalf of the Scientific Advisory Committee to the Cabinet, we had the privilege of organizing a meeting of scientists of the Academy to discuss the problem of Excellence in Science in India—its identification, nurturing and upliftment. I am sure that every distinguished Fellow would admit that there has been a serious trend towards the breeding of mediocrity in this country which is actually swamping excellence. Sparks of excellence are only sporadic. The Fellowship is deeply conscious of this problem and concrete recommendations have emerged which have been forwarded to the Scientific Advisory Committee to the Cabinet for implementation. We had the opportunity of discussing this issue during the meetings of the Committee. We hope that with the involvement of the Academy and the help of Fellowship it will be possible to work out a *modus operandi* for its solution, particularly since our immediate Past-President, Professor MGK Menon is the Chairman of the SACC.

The Science Policy Resolution, which has completed 25 years of promulgation, is also being discussed. Already, on your behalf I had participated in the discussions held in the Academy premises organised by the INSTADS on the benefits which have accrued out of the Science Policy Resolution of 1958, of the lacunae still existing and methods of filling the gaps

Also we have constituted working groups for publishing documents dealing with the state of the art for Energy, the problems of Population Control, Food, Technical manpower training and Environment which will serve as guidelines for policy makers at the national level. In increasing the coordination between the scientists, institutions, Academies etc. at national and international levels, the Academy has sponsored a number of symposia in collaboration with scientists of different disciplines throughout India. Several International Conferences have been organized including International Cosmic Ray Conference held at Bangalore and COSPAR meeting at Delhi.

In order to fulfil the objectives of the Academy for affecting coordination between scientific societies and for the application of scientific knowledge in national welfare, a meeting has been arranged from December 1 to 5 at Delhi of the Continuing Committee of Global Seminar held in 1980 involving the Academy, the Indian Science Congress Association and the American Association for Advancement of Science. The programmes on the agenda include discussions on the manufacture and use of biomedical equipments; computer technology, forestry, microbiology and others in which both US and Indian societies can be involved. The Academy is also organizing a meeting of the heads of Academies of South Eastern Asian countries including Singapore, Thailand, Malayasia, Afghanistan, Burma, Nepal, Bangladesh and others on the Role of Scientific and Engineering Societies in Development. This is principally aimed at working out a mode of cooperation for solving regional problems in which INSA can play a leading role, especially as a catalysing agent.

At the international level, in addition to this cooperation envisaged between the developing countries of South-east Asia, your academy has entered into new agreements with the Academy of Science of Philippines, the French Academy of Sciences, the Polish Academy of Sciences, and this month the agreement with the Norwegian Academy will be signed by me on your behalf. A similar agreement is expected to be made with the US National Academy of Sciences. During my visit to the USA, sponsored by the AAAS, Dr. Frank Press, the President of US Academy of Sciences and I had discussed the immediate need for a continued cooperation between these two premier Academies. The agreement with the Royal Society, London has been further strengthened with almost double financial input recently agreed on by the Royal Society. It was conveyed to us by Sir Arnold Bergen, Vice-President and Dr. Ernest Keay, the Executive Secretary of the Society during their visit to our Academy last month.

One of the important issues in which I hope you will agree with me is that the Academy as a body of scientists has not yet looked into the problem of status of scientists in the country, particularly of safeguarding their interests. This is a vital issue to which the Fellowship should give a serious thought. The indignity to which the scientists are often exposed and the trivia of bureaucratic procedures which are seriously undermining our culture must be given due attention by the academicians of this country and an active role must be played by the Academy in their eradication.

In the Basic Sciences Committee we have made a slight departure from this year in our policy. During the initial phase when this committee started functioning, the basic philosophy was to finance projects of a novel and creative nature. Unfortunately in recent years these have become stereotyped and routine and the Academy has been acting as a grant-giving agency. In order to make it more meaningful, it has now been decided that the young scientists' programme, which is paying high dividends, is to be encouraged with seed grant for projects but other projects would have to be substituted by commissioning of reports by selected scientists in the field and preferably from the Fellowship.

One of the important activities of the next year, the responsibility for which the entire Fellowship is to shoulder, is the celebration of the Golden Jubilee of the Academy. The initiation of the celebrations will be inaugurated by the Prime Minister on the evening of January 16, 1984. The Presidents of the corresponding Academies of the world, including those of the Royal Society, London, the US National Academy of Sciences, the French Academy of Sciences, the Polish Academy of Sciences, the USSR Academy of Sciences, the Japan Society for Promotion of Science, the Hungarian Academy of Sciences etc. have all agreed to participate in the celebrations. The initial programme will last for three-days from January 16 to 18, 1984 concurrent with the deliberations of the sectional committees in order to enable a significant proportion of the Fellowship to be present during the meetings. It will include a series of lectures in addition to the Blackett memorial lecture to be delivered by Sir Andew Huxley, President, the Royal Society, London. In order to enable the Fellows to attend the celebrations it has been decided to bear the travel cost by train of those who may need it. On this occasion a series of publications have been commissioned including a compendium of all Fellows of the Academy; another of all young scientists selected; a compilation of the bibliographies of the Presidents and presidential addresses delivered; a volume containing endowment and medal lectures given so far and a series of perspectives and other reports on different areas of physical, chemical, and biological sciences, several of which will be ready at the time of inauguration. Simultaneously, throughout the year several international symposia will be organized in different disciplines all over the country. It has been decided to build a 5-storied annexe on the western side of the Academy premises, not only to meet the urgent requirements of space for the expanding activities of the Academy but also to further the liaison between the adhering Academies and Scientific and Engineering societies in India, including the provision of several guest rooms. It has been planned as a sort of science complex in which the Academy will serve as an umbrella for other scientific and engineering societies of India. The Academy is depending on the help and cooperation of Fellowship for the fulfilment of these objectives, both financially and otherwise.

Lastly, I would like to say a few words about the autonomy of the Academy. It is undoubtedly an autonomous organization, the highest scientific organization in the country and the adhering body of International Council of Scientific Union on behalf of the Government of India. In order to meet its expanding activities and to fulfil its charter of objectives, it must have financial autonomy as well, as is enjoyed by the Royal Society, London and the National Academy of Sciences, USA. The grant at present allocated to the Academy is too meagre to support all the activities, both current and those to be expanded, to fulfil the objectives of its charter. We are also fully aware of the limitations under which the Department of Science and Technology has to function within its limited resources It is therefore, imperative that the allocation for the commitments of the Indian National Science Academy should be decided at the highest national level and be adequate to finance its objectives, including the programmes undertaken for the Golden Jubilee celebrations. Our government is committed to the culture of excellence in science on the one hand and to the generation of awareness and base of science and technology on the other. Under such conditions, it is paradoxical that the Indian National Science Academy which is the emblem of the highest level of excellence in this country in science is not receiving funds adequate to expand its essential activities. On behalf of the entire Fellowship it will be my privilege to take this matter up with the Government and hope that the Academy would be able to not merely meet its present financial needs but would also be given the status which, as the highest scientific organisation of this country, it fully deserves and demands.

ADDITIONAL GENES—ENIGMA IN BIOLOGY

A K SHARMA

(delivered at Ranchi, 1984)

It is a pleasant duty for me to express my deep gratitude to the Fellowship of the Indian National Science Academy for electing me as the president of this august organisation. It is the custom for the President to deliver an address at the anniversary meeting, usually on a scientific theme. Having been deeply involved in chromosome research for the last four decades, I thought that I would speak on an aspect of chromosome structure and its implications.

Preamble

The evolution of present-day organisms has been traced to an era three billion years ago During this intervening period, there has occurred a marked evolution in the genetic system. The mechanism through which the present-day plant and animal species have been derived from the earliest living forms like the viruses and the amoeba is still a problem unsolved. One of the reasons for this nebulous state of our knowledge is the absence of any fossil evidence connecting the present-day man to the minute forms of life.

Even though Charles Darwin is not considered as the father of genetics, yet his very doctrine of evolution led to the theory that every organism is a descendent of the pre-existing past. This continuity of life, from generation to generation since its creation, in the universe as enshrined in Darwin's concept, forms the basic foundation of the science of heredity.

It is needless to emphasize to such a learned audience that in every biological system, the expression of a character is the ultimate manifestation of a chain of chemical reactions triggered at the level of the gene in the chromosomes, located inside the nucleus of a cell. Such a genetic control is universal whether it involves the singing of a bird, the flowing mane of a lion, the reproduction of flowering plants or even the abstract qualities that characterize the human species—*Homo sapiens.* The chromosomes thus hold the key to an understanding of control and expression of genetic characters.

The study of the genes includes a detailed analysis of the finer structure of chromosomes at the molecular level. Deoxyribonucleic acid molecule, or in short DNA, has been unequivocally shown to be the gene substance specially on the basis of its three essential properties of autocatalysis, heterocatalysis and mutation. In other words it can produce its own replica, it can catalyse a chain of reactions and it has the capability of undergoing change for generating variability so essential for evolution. The second property of catalysing the reactions is most vital in the sense that DNA confers specificity on the enzymes which ultimately control all the metabolic pathways to the organism. In fact each and every character is the product of one or more reactions, each step of which is controlled by specific enzymes. The enzymes are proteinaceous in nature and their specificity lies in the varied arrangements of the amino acids in the polypeptides. The mechanism through diversity, provided by only the four alphabets of DNA—Adenine, Guanine, Cytosine and Thymine, ultimately leading to the specificity of amino acids of protein chain, forms the fascinating topic of genetic code. The genetic code is too well known to be discussed. In any case, the very fact that millions of characters inherent in different organisms, starting from the lowest known living forms to man, are ultimately formulated by arrangements of four alphabets of DNA is a remarkable example of the control of most complex reaction by simplest possible operational process. The simplicity of the genetic code is possibly a reminder of the basic philosophy in evolution of combining the maximum efficiency with the minimum expenditure of materials.

Chromosome Structure

The chromosome, as it is visualized at present, is made up of fibrils 20 to 30A° in diameter folded several times to yield a fibre, 100A° in thickness. Thus a chromosome represents a long chain deoxyribonucleic protein fibre with alternating condensed and decondensed segments. The long chain fibre is composed of several replicating units, the *replicons*,—the chromosome thus being multi-repliconic in nature. The beaded appearance of chromosomes has been shown to be due to the presence of structures made up of four types of histones encircled by the DNA fibre, the so-called *nucleosomes*. Each nucleosome is composed of five different kinds of histones of which four enter into the composition of the core and the fifth one serves as the linker. Around each nucleosome the DNA fibres are almost 200 base pairs long. Of these 120-140 are conserved and the rest are variable and associated with the linker [1,2,3].

One of the outstanding discoveries in recent years has been the demonstration of the split nature of the gene. Each gene is composed of several essential sequences separated from each other by so-called non-essential intervening sequences referred to as *exons* and *introns* respectively. This specialized structure clearly differentiates the chromosomes of higher organisms, including man, from those of almost all viruses and *Amoeba*, and thus has a tremendous implication on chromosome evolution.

Several relatively recent outstanding discoveries have been responsible for a greater understanding of chromosome structure. The demonstration of the enzyme *reverse transcriptase* enabled the scientists to synthesize the complementary or gene DNA molecule from readily available messengers. Restriction enzymes, ligases and molecular hybridization allowed an analysis of sequence complexity of chromosomes as represented *in vivo*. A remarkable development aided through the application of these methods is the localization of multiple copies of similar sequences in the chromosomes, termed as *repeated sequences*. The application of restriction enzymes has facilitated the study of sequence complexity even within long apparently repeated sequences. Repeats may be highly homogeneous, such as the satellite DNA in *Xenopus*, moderate, and minor, mostly interspersed within the nonrepeated sequences in the chromosomes. There has been a general agreement that the chromosome can be visualized as a linear array of potentially independent replicons with major repeats at a lower number of loci and minor or moderate repeats interspersed throughout.

Repetitive DNA Sequences

Initially observed in a few organisms, the repetitive sequences have gradually become the focus of attention due to their presence on several loci on chromosomes. Even in the gene structure itself, the introns referred to earlier contain principally amplified sequences. Their occasional location in exons too has been recently claimed. The presence of repeats in spacers, often heterogeneous in nature, is also on record. The jumping genes or *transposons* which are transposable elements are mostly associated with a high degree of repeats It is claimed that the repeats often flank the non-repeats or unique sequences to secure effective padding essential for efficient functioning of the uniques. The amplified sequences in ribosomal DNA have been precisely localized. The species of DNA often termed as *nucleotypic* which principally control non-specific functions such as chromosome volume, cell volume, generation time and several other biophysical parameters, also contain multiple copies of similar sequences. The term *dynamic DNA* has been given to repeats which have the property of amplification, dispersion and mobility as manifested in the presence of similar sequences in different sites and transposable capacity[2,4].

The single long repetitive segment may also be heterogeneous in nature as evidenced in the presence of several restriction sites often identified by endonucleases. Such heterogeneity amongst a single sequence may indicate either insertion or mutation. In view of the property of mobility the possibility of insertion can not be ruled out. In addition to the moderate repetitive sequences, minor repeats are more difficult to resolve and often remain closely associated with the non-repeated ones.

Notwithstanding the fact that their function is still obscure the presence of high amounts of repeats can hardly be considered to be without any significance. In the plant system as in rye and a few other crops nearly 70-75% of DNA have been found to be repetitive. In the human system almost 40% of DNA is composed of repeats of which 6-10% are highly repetitive. There are, on the other hand, organisms such as *Aspergillus nidulans*, where more than 95% of DNA are of unique type.

C-value paradox

The presence of high amounts of such amplified sequences is of special significance if one compares the DNA values of allied as well as of widely different species. In the wide canvas of the biological system the DNA values present a perplexing situation. The lilies, amaryllids and even the amphibians show a range of 20-300 picograms of DNA/cell nucleus as compared to 2-3 picograms in mammals and approximately 7 picograms in man. The increase in histological complexity concomitant with structural diversity and differentiation can not evidently be correlated with increase or decrease of DNA. It is a situation where highly complex organisms have lesser amount of genetic material as compared to the comparatively simple and primitive forms. This is indeed a paradoxical situaion rightly termed as *C-value paradox*. This paradox is even more manifested in the wide range of DNA variation shown by related species within the same genus. Amongst the angiosperms the range in diploid nuclear DNA content is more than 350 times as noted in 0·8 picogram in *Arabidopsis* to 2·9 picogram in *Fritillaria*. Within the same family as Ranunculaceae, there exists a range of upto 40 times in DNA content[5]. In the genus *Vicia* alone, DNA content of the different diploid species shows a significant variation[6].

The wide difference in DNA amongst related species is principally due to the amplified sequences. Such repeats may originate out of saltatory replication or unequal crossing over but insertion or translocation too can not be ruled out. Obviously, there is a systematic mechanism in the biological system to either maintain, accelerate or delete the repeats during evolution All these aspects need to be considered in their totality in order to have a better understanding of the process of amplification leading to additional genetic elements in different organisms.

Ontogenetic Increase

In any discussion on additional genetic materials or amplification of genes, the ontogenetic increase in DNA, which is phase-specific during differentiation, can not be excluded. The very dogma that each and every cell of an organism contains the same number and type of chromosome to facilitate equal opportunity for the genes to exert their influence, though correct in its fundamentals, yet needs further modification. It was first suggested by Pelc[7] that in *Vicia faba* the amount of DNA varies to a significant extent from the meristematic to the differentiated zone. Cook[8] recorded that cellular differentiation is controlled by the development of high order of chromosome polymorphism especially in relation to metabolic DNA. In *Petunia hybrida* similar metabolic DNA has been recorded. An extreme case is seen in the sea urchin embryo where there is a two thousand-fold increase in nuclear DNA from egg to the pluteus stage. Several instances have been reported from our group, clearly indicating the association of lateral amplification of DNA with differentiation. Such amplified sequences need not necessarily involve the entire genome and may be only partial, including a few segments. Amplifications of DNA in root development of *Allium cepa*[9], epicotyl of *Vicia faba*[10] and a host of others are on record[11].

The variable content of DNA due to differential amplification is characteristic of different organs of individuals. The increase in DNA content during differentiation is considered as associated with need for rapid and continued protein synthesis. The amplification of DNA arising out of endomitotic replication of chromonema is a mechanism to meet the requirements of protein synthesis during differentiation. This method of replication and lateral amplification ensures the steady supply of DNA imperative for uninterrupted enzyme and structural protein synthesis during differentiation, without causing any disruption in the predetermined symmetry of an organism by cellular growth[12].

The need for additional amount of DNA during differentiation has been well documented from series of publications from our laboratory. The process evidently is under genetic control. It has been suggested that the plants have a mechanism of phylogenetic increase in nuclear DNA through polyploidy and repetitive sequences. Such additional elements are adequate to meet the exigencies of differentiation. In species where there is no phylogenetic increase, the organisms had to develop an evolutionary strategy of ontogenetic increase in nuclear DNA through endomitotic replication. The need for amplification of genetic materials in the regulation for differentiation is clearly recognized and ontogenetic increase too is adequately accounted for.

Phylogenetic increase and additional DNA sequences in chromosome architecture

The amplification of DNA or the genetic material during the ontogeny of an individual, as discussed earlier, implies the origin and transitory appearance of additional genetic material of chromosomes during the phasic development of an individual. Such a state of chromosome should be clearly distinguished from the phylogenetic increase, which involves the origin of multiple copies of DNA sequences in the chromosome architecture of permanent genetic stability. Such repetitive sequences, as already mentioned, may arise out of saltatory replication and unequal crossing over. Their wide occurrence in biological system has been clearly indicated. Leaving aside their probable role in differentiation[13], which can be accomplished even by endomitotic replication in ontogeny, a clear understanding of their function is essential.

It is being argued that replication may occur due to the capacity of particular segments to duplicate in a congenial cellular environment without necessarily having any possible cellular function. Even such DNA may be harmful to the organism as in segregation distortor locus in *Drosophila*. It is, however, difficult to reconcile the basic principles of evolutionary targets, ensuring maximum efficiency with minimum expenditure with the concept of selfish DNA sequences[14]. The fact that these have been maintained throughout a long antecedent period of evolution, surviving the rigours of selection, is itself an evidence of their adaptive significance.

The properties of amplification, dispersion and mobility have on the other hand enabled such sequences to exert a dynamic and supreme influence on various facets of the life process[2,4].

Functions

The presence of similar genes at certain sites, which may secondarily serve as potential loci for accumulation of mutants, may have an adaptive importance. However, it has been argued that as evolution is not anticipatory, such sequences may not be regarded as reservoir of mutations. It is true that the functional importance of amplified sequences is not fully understood, but the evidences for their conservation in various groups of organisms at multiple loci can hardly be ignored. Their presence has been recorded as intragenic introns in *Tetrahymena*[15], heterochromatic knobs in maize[16], interspersed repeats in mouse, *Xenopus* and man[17], moderate repeats in species of *Lilium*[18] and primates in general including man, gorilla and chimpanzee[19].

There has also been an extensive change in DNA content with the progress of evolution. Such variations exist within a species and among related species and can not be necessarily correlated with evolutionary advance or structural complexity. On the other hand, in reptiles[20] species difference has been attributed to the difference in DNA content In fact, the decrease and increase in DNA content have been explained on the basis of selection, duplication and deletion of regulatory sequences. In general there is a fifteen fold variation in plant families[21]. In several cases interspecific variation has been correlated to geographical parameters such as latitude. It is true that the acquisition or deletion of DNA sequences leads to C-value paradox. The correlation of amplified DNA with the volume of the nucleus, cell, chromosome size, mitotic cycle and other biophysical parameters may have both biological and evolutionary significance.

In addition to such non-specific effects the importance of amplified sequences in higher biological systems has been found to be rather varied in nature. The satellite DNA is known to have a specific role in ribosomal RNA formation[22]. It has also been observed to occur in a random position in early embryogenesis in *Drosophila viridis*[23]. Such A-T rich sequences have been consistently located on nuclear sites nearest to the membranes, indicating possibly their role in nucleo-cytoplasmic transfer. Such association may have a significant bearing in communication mechanism[24]. The presence of amplified sequences in heterochromatin, which otherwise plays an important role in nucleocytoplasmic transfer, is relevant in this connection. The satellite DNA, because of its homogeneity and large number of sequences, helps in maintaining the structural integrity of chromosomes. The recognition of homologous segments during recombination in meiosis is one of its roles in signalling processes. The heterogeneity of repeats, in certain cases, is associated with heterozygosity[25]. The capacity of transposition and interspersion may have profound functional significance as well.

The interspersed repeats possibly play a much more important role than the satellite DNA in biological systems. Such interspersion of moderate repeats in *Lilium* undergoes specific repair synthesis during pachytene[18]. Their conservation indicates a strong selection pressure for proper functioning of meiosis. The role of such amplified sequences in the regulation of chromosome structure is manifested in their involvement to facilitate pairing[26]. The continuous addition of amplified sequences in cultured cells of *Drosophila* is not without any significance during selection. A very profound role of repeated sequences in gene conversion and expression has been indicated in fission yeast[27]. A very powerful tool of genome exchange is the exchange between the reiterated genes resulting in intergenic conversion and reappearance of often active alleles. The exchanges also occur within large repeated gene clusters of the globin regions of the Asian and Caucasian human systems[28]. In *Saccharomyces perpuratus, in situ* RNA hybridization can be achieved only if non-repetitive sequences are linked with repeats[29]. In different organisms amplified sequences are responsible for coding transfer ribosomal RNA histones. All the five genes coding for sea urchin histone are repeats[30]. Various functions, including the role in evolution, have thus far been attributed to such moderate and minor repeats showing interspersion.

Similarly inverted repeats or *palindromes*, because of their consistent presence at specific loci, could be assigned specific functions. They are often termed *fold back* or *snap back* DNA. Polymorphism in inverted repeats too is very common[31,32]. More than one functions are often attributed to palindromes. Intense replication is often a special function[33]. A large part of comparatively long palindromes is associated with replication Its role in specific protein synthesis at different levels has also been suggested[34].

The recognition of different processes at DNA and RNA levels, involving deletion and translocation of genes, has been visualized[35]. The role of amplified sequences is quite significant in the recognition of cleavage sites, termination of transcription and binding of regulatory proteins during protein synthesis[36] and in attachment of chromosomes to each other[37]. All the different data so far obtained simply indicate that the palindrome serves multiple functions and preservation of such loci clearly indicates a selective advantage. The introns with high degree of repeats are capable of giving rise to new translatable transcripts and a range of structural proteins through reshuffling of sequences The code for different allied antibodies may thus be stored in a single gene sequence capable of having different exon combinations. The location of repeats in transposons allows dispersion to a certain extent. The mobility permits dispersion as well as accumulation of a segment at a specific locus. It is not unlikely that such mobile sequences may help in accelerating accumulation of mutations and promotion of genetic diversity.

In spacers the repeats are rather frequent[37]. Such sequences may often be heterogeneous clusters[22]. The occurrence of detectable dissimilar fifty five gene clusters in *Xenopus* has been taken to suggest a common control through a few sequences. In maize nontranscribed spacer sequences contain several tandem copies and several subrepeating units.

The term *dynamic* DNA[2] proposed for all such amplified sequences, having the capacity for amplification, dispersion and mobility, encompasses clearly the nonspecific and vital functions of cell including nuclear behaviour, cell volume and chromosome size. The specific role in messenger processing, reshuffling of exons or structural sequences and maintenance of integrity of chromosome structure, by providing padding and through other functions, have been clearly brought out The repeats are considered simultaneously as a natural mechanism for a steady supply of genetic diversity The concept of redundancy can hardly be reconciled with optimization of efficiency against rigours of selection in evolution. The mobility and dispersion of amplified sequences at multiple sites not only promote genetic diversity but are strategies against complete elimination.

Evolutionary Significance

It is true that the evolutionary significance of reiterated sequences is not precisely known Evolutionary growth of a genome may involve accumulation of redundant sequences which in all possibility have a role in genetic regulation It has been shown that only a fraction of structural DNA codes for structural or enzyme proteins. If the regulatory role is to be assigned to repeated sequences along with non-specific functions, its quantitative increase should have some relationship with increase in complexity at all levels.

The increase in histological and biochemical complexity must necessarily be associated with a quantitative and qualitative acceleration of enzyme activity. Both these facets of metabolism require continued transcription and translation. Regulatory sequences play a significant part in repression and derepression. In order to meet these demands additional amount of DNA is necessary.

This extra DNA, whether for non-specific or regulatory function, is generally provided through phylogenetic increase in the amount of DNA involving high degree of amplification or polyploidy.

However, in biological systems with progress in evolution the predetermined symmetry of an organ in a complex differentiated system is an inherent factor. In such a system, a large amount of DNA is not congenial for growth and development which would necessitate large cell volume, cell size, long generation time and other associated features. In order to meet this challenge in evolution, the genetic alteration leading to ontogenetic increase in DNA through endomitotic replication has been adopted as a strategy. This genetically controlled increase in DNA during ontogeny may involve part or whole of genome depending on the need for differentiation Once this property is acquired at a certain level the necessity of phylogenetic increase is minimised.

In the hierarchy of evolution in advanced eukaryotes the amount of DNA specially of the repetitive sequences is not as high as maybe expected on the basis of the amount in lower groups of plants and animals. With the moderate amount of repetitive sequences controlling non-specific factors and regulation in the genome, the development of the process of ontogenetic increase automatically meets the necessity for additional amounts during differentiation. The origin of introns in eukaryotes, consisting principally of reiterated sequences, has a significant role in the rearrangement of exons to satisfy the need for varied gene products from a single locus. In fact such sequences are satisfying the need of several genes from a single gene locus. It is an example of optimal efficiency through amplification without necessarily involving a large number of structural genes. The evolutionary progress, at a certain level, has very likely been associated with the addition of amplified, mobile and dispersed sequences which are undoubtedly dynamic in their property. In order to secure maximum efficiency in evolution and to meet the optimum needs in a differentiating system localization of these dynamic sequences at certain specific loci to control regulation and several non-specific and vital functions is necessary. The additional amount needed, over and above the phylogenetic increase, is satisfied by the development of ontogenetic mechanism of of DNA amplification.

In advanced biological systems, including *Homo sapiens,* a balance between phylogenetic and ontogenetic increase is one of the principal features of evolution. The C-value paradox can only be accounted for through an understanding of the basic features of evolution which underly phylogenetic increment up to a certain level, followed by genetic control of addition of genetic materials during ontogeny The evidences for such an approach towards evolution are to be derived through experimental induction of phylogenetic and ontogenetic increase of genetic materials. A synthesis of these two basic aspects of evolution would lead to a clear understanding of the role of additional genetic materials in evolution.

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